ARTICLE IV.

On two Storms which were experienced throughout the United States, in the month of February, 1842. *By Elias Loomis, Professor of Mathematics and Natural Philosophy in Western Reserve College. Read May* 26, 1843.

THE favour with which my account of the storm of December 20, 1836, has been received, has induced me again to undertake a similar investigation. A remarkable tornado was experienced in the north-east part of Ohio, February 4, 1842, an account of which may be found in the American Journal of Science, Volume xliii., pages 278—300. I was induced to hope that a careful investigation of the phenomena of the general storm which accompanied the tornado, might throw some light upon the origin of the tornado itself. Hence this storm was selected for investigation. Another very remarkable storm having been experienced about the middle of the same month, it occurred to me that I might obtain the materials for an investigation of both storms with about the same ease as for one. In collecting these materials, I have to acknowledge my obligations to my correspondents. To Professor Bache, I am indebted for a copy of the observations made in the State of Pennsylvania. To Professor Espy, I am indebted for a large mass of information he has, with great pains, collected, and which he has generously placed at my disposal. The remaining observations were chiefly obtained by direct application to the observers. I have thus obtained sixty-eight registers, containing barometric observations. The situation of the stations, and the authority upon which the observations rest, are shown in the following table.

STATION.	LATITUDE.	LONG.	AUTHORITY.
Natchez, Mississippi,	31° 34′ N.	91° 25′	Dr. Henry Tooley.
Vicksburgh, Mississippi,	32 24	91 6	N. W. Hatch.
Bloomington, Iowa,	41 26	91 2	T. S. Parvin.
New Orleans, Louisiana,	29 58	90 7	D. T. Lillie.
St. Louis, Missouri,	38 36	89 36	Dr. B. B. Brown.
Mobile, Alabama,	30 42	87 59	Dr. Stephen B. North.
Pensacola, Florida,	30 28	87 12	Isaac Hulse.
Nashville, Tennessee,	36 10	86 49	Professor James Hamilton.
Louisville, Kentucky,	38 3	85 30	Thomas S. Caldwell.
Cincinnati, Ohio,	39 6	84 27	Professor Joseph Ray.
" "	39 6	84 27	M. G. Williams.
Athens, Georgia,	33 59	83 32	Professor C. F. M'Coy.
Portsmouth, Ohio,	38 48	83 3	Dr. S. B. Hempstead.

STATION.	LATITUDE.	LONG.	AUTHORITY.
Detroit, Michigan,	42°24′ N.	82°58′	Rev. George Duffield.
Chillicothe, Ohio,	39 21	82 55	Dr. E. H. Davis.
Marietta, Ohio,	39 25	81 26	Dr. S. P. Hildreth.
Hudson, Ohio,	41 15	81 27	Professor Elias Loomis.
Savannah, Georgia,	32 5	81 7	Dr. John F. Posey.
Meadville, Pennsylvania,	41 39	80 16	Henry Shippen.
Erie, Pennsylvania,	42 7	80 12	James C. Reid.
Pittsburgh, Pennsylvania,	40 32	80 2	J. P. Bakewell.
Butler, Pennsylvania,	40 52	79 58	Jacob Mechling.
Charleston, South Carolina,	32 47	79 57	Robert Lebby.
Franklin, Pennsylvania,	41 24	79 55	William Connelly.
Uniontown, Pennsylvania,	39 54	79 48	President J. P. Wecther.
Toronto, Canada,	43 33	79 20	Magnetic Observatory.
Somerset, Pennsylvania,	40 0	79 6	George Mowry.
Ebensburgh, Pennsylvania,	40 31	78 46	Richard Lewis.
Bedford, Pennsylvania,	40 1	78 29	Samuel Brown.
Millville, New York,	43 8	78 20	James F. Cogswell.
Huntingdon, Pennsylvania,	40 32	78 1	Professor Jacob Miller.
Rochester, New York,	43 8	77 51	Rev. Chester Dewey.
Nassau, Bahamas,	25 16	77 48	Honourable John C. Lees.
Bellefonte, Pennsylvania,	40 55	77 48	John Harris.
Mifflintown, Pennsylvania,	40 34	77 24	J. A. Kinkead.
Gettysburgh, Pennsylvania,	39 49	77 11	Professor M. Jacobs.
Carlisle, Pennsylvania,	40 13	77 10	Professor W. H. Allen.
Washington, Dist. of Columbia,	38 53	77 1	Lieutenant Gilliss.
Harrisburgh, Pennsylvania,	40 16	76 50	J. Heiseby.
Northumberland, Pennsylvania,	40 53	76 50	Andrew C. Huston.
Lancaster, Pennsylvania,	40 3	76 21	Conservatory of Arts.
Gosport, Virginia,	36 51	76 19	William F. Patton.
Port Carbon, Pennsylvania,	40 45	76 7	P. C. Lyceum.
Casenovia, New York,	42 55	75 46	H. R. Clark.
West Chester, Pennsylvania,	39 57	75 30	E. W. Beans.
Haverford, Pennsylvania,	40 1	75 19	Haverford School.
Philadelphia, Pennsylvania,	39 57	75 10	Owen Evans.
" "	39 57	75 10	John Conrad.
Newtown, Pennsylvania,	40 14	74 49	L. H. Parsons.
New York City,	40 43	74 1	William C. Redfield.
" "	40 43	74 1	Professor B. F. Jortin.
" "	40 43	74 1	B. Ticknor.
North Salem, New York,	41 22	73 44	John F. Jenkins.
Montreal, Canada,	45 31	73 35	John S. M'Cord.
Williamstown, Massachusetts,	42 43	73 13	G. F. Bigelow.
New Haven, Connecticut,	41 18	72 58	Connecticut Academy.
Amherst, Massachusetts,	42 22	72 32	Professor E. S. Snell.
Hanover, New Hampshire,	43 41½	72 22	Professor Ira Young.
Worcester, Massachusetts,	42 16	71 48	Lunatic Hospital.
Providence, Rhode Island,	41 49	71 25	Professor Alexis Caswell.
Cambridge, Massachusetts,	42 22	71 8	William C. Bond.
New Bedford, Massachusetts,	41 38	70 56	S. Rodman.
Portsmouth, New Hampshire,	43 5	70 46	Charles Chase.
Nantucket, Massachusetts,	41 17	70 6	William Mitchell.
Gardiner, Maine,	44 10	69 50	R. H. Gardiner.
Waterville, Maine,	44 35	69 41	Professor George W. Kesly.
Bermuda Islands,	32 34	63 28	Thomas Phillips.
St. John's, New Foundland,	47 34	52 38	Joseph Templeman.

I have obtained observations from the following military posts, but they give no record of the barometer.

POSTS.	LATITUDE.	LONG.	POSTS.	LATITUDE.	LONG.
Fort Gibson, Arkansas,	35°47′ N.	95°19′	Augusta Arsenal, Georgia,	33°27′ N.	81°33′
Fort Leavenworth, Missouri,	39 28	95 14	Alleghany Arsenal,	40 28	80 7
Fort Towson, Arkansas,	33 36	95 4	Fort Niagara,	43 14	79 7
Fort Smith, Arkansas,	35 20	94 21	Buffalo Barracks, New York,	42 53	78 55
Fort Wayne, Arkansas,			Carlisle Barracks, Pennsylvania,	40 12	77 10
Fort Jesup, Louisiana,	31 35	93 42	Fort M'Henry, Maryland,	39 18	76 35
Fort Snelling, Iowa,	44 53	93 12	Fort Monroe, Virginia,	36 50	76 22
Fort Atkinson, Iowa,	43 0	92 1	Madison Barracks, New York,	43 45	76 1
Fort Crawford, Wiskonsin,	43 4	91 7	Fort Columbus, New York,	40 41	74 1
Jefferson Barracks, Missouri,	38 32	90 25	Fort Wood, New York,	40 42	74 1
St. Louis Arsenal, Missouri,	38 37	90 21	West Point, New York,	41 25	74 0
New Orleans Barracks,	29 57	90 9	Watervliet Arsenal, New York,	42 45	73 45
Fort Winnebago, Wiskonsin,	43 32	88 53	Plattsburgh, New York,	44 42	73 32
Fort Mackinac, Michigan,	45 46	84 40	Fort Adam, Rhode Island,	41 20	71 19
Fort Brady, Michigan,	46 29	84 18	Fort Constitution, New Hampshire,	43 4	70 45
Fort Robert Gamble,	30 25	83 31			
Dearbornville Arsenal, Michigan,	42 24	83 2	Fort Preble, Maine,	43 39	70 20
Detroit, Michigan,	42 24	82 58	Fort Kent, Maine,	47 15	68 46
Fort Gilmer, Georgia,	30 40	82 52	Fort Fairfield, Maine,	46·50	68 0
Fort Gratiot, Michigan,	42 54	82 25	Hancock Barracks, Maine,	46 8	67 51
Fort Henderson, Georgia,	30 45	82 10	Fort Sullivan, Maine,	44 54	66 56

I have also received observations from eighteen posts in Florida, but have made little use of them. I have received observations of the thermometer, etc., but not of the barometer, from the following places.

STATION.	LATITUDE.	LONG.	AUTHORITY.
Mount Atlas, Carroll Co., Tenn.,	36° 0′	88°30′N.	Dr. John Travis.
Carmi, Illinois,	38 5	88 13	W. H. Sorgenfrey.
Indianapolis, Indiana,	39 55	86 5	John Wheeler.
Washington, Michigan,	42 43	82 56	Dennis Cooley.
St. Mary's, Georgia,	30 44	81 46	S. R. Williams.
Ravenna, Ohio,	41 10	81 13	Newton Peck.
Lockport, New York,	43 11	78 46	Edward Giddins.
Gaines, New York,	43 16	78 26	M. Mason, M.D.
Winchester, Virginia,	39 11	78 13	Anonymous.
Williamsburgh, Virginia,	37 16	76 40	Alexander D. Galt.
Sacketts Harbour, New York,	43 55	75 57	Zeno Allen.
Utica, New York,	43 7	75 13	S. Aylesworth.
Clermont Academy, near Frankford, Pennsylvania,	40 0	74 55	Samuel S. Griscom.
Trenton, New Jersey,	40 14	74 30	Francis A. Ewing.
Malone, New York,	44 51	74 15	E. N. Winslow.
Albany, New York,	42 39	73 45	Dr. Phillips Ten Eyck.
Middleton, Connecticut,	41 33	72 39	Joseph Barrett, M.D.
Grafton, Vermont,	43 11	72 35	A. Putnam.
Newport, Rhode Island,	41 29	71 19	R. J. Taylor.
Portland, Maine,	43 39	70 20	Samuel Moody.
Charleston, Maine,	45 5	69 0	E. M. Thurston.
Eastport, Maine,	44 54	66 56	S. B. Mitchell.

Some memoranda of the weather, but without observations either of the barometer or thermometer, have been received from several other stations. As I intend this paper for a continuation of my former investigations, I shall dispense with a good deal of preliminary explanation which might otherwise seem called for.

Storm of February 16, 1842.

I have represented the principal phenomena of this storm on the accompanying charts, one to five. Those regions, where the sky was unclouded, or where the cloudiness was less than one half, are coloured blue; those where the sky was entirely overcast, or the cloudiness exceeded one half, but without rain or snow, are coloured brown; the fall of snow is indicated by the green colour, and rain by the yellow. The direction of the wind is represented by the arrows, and its force is, to a certain extent, indicated by their length. When, however, the winds were faint, the arrows, if drawn of a strictly proportionate length, would have been too short to attract notice, and are therefore somewhat magnified. A calm is represented by a cipher, (0). I have also represented the barometric, and thermometric observations in the following manner: Having determined, as well as I was able, the mean height of the barometer at each station, I compared each observation with the mean. I then drew a line passing through all the places, where the barometer stands at its mean height. This line is marked — — 0, and may be called the line of mean pressure. I then drew a line through all the places where the barometer stands two inches above the mean. This line is marked — — — + .2, and so of the others. In like manner, a line joining all those places where the thermometer stands at its mean height for that hour and month, is marked . . . . . 0°, and may be called the line of mean temperature. Another line joins all those places where the thermometer is 10° above the mean, and is marked . . . . . . 10°, and so of the others. Nearly every circumstance essential to a correct understanding of the phenomena of the storm is thus presented to the eye at a single glance.

Chart 1. for the morning of February 15, represents the storm near its commencement, and before it had acquired much violence, or its features had become very distinctly marked. In the extreme north-eastern part of the United States, is seen a corner of a storm rapidly passing off. In the vicinity of Buffalo, a few particles of snow are falling, and the sky in its vicinity is overcast. Perhaps this may be ascribed to the vapour arising from the lakes, aided by the rise of ground as the current travels eastward, by which means the moist air at the surface is forced up to a region of greater elevation and cold, and its vapour condensed. With these exceptions, nearly the whole eastern and central portions of the United States are unclouded. But throughout the valley of the Mississippi, the heavens are obscured, and in the northern part some snow is falling. This is the commencement of the storm which I propose particularly to consider. Throughout the entire United States the barometer stands a little above the mean. The line of — — — + .2, is marked upon the chart. The thermometer no where stands much above its average for February. The line of mean temperature passes nearly through the middle of the United States; and that of 10° below the mean, is an undulating line in the eastern part of the United States. The direction of the winds is exceedingly various. In the eastern part of the United States, the winds are generally north-west, the result of the preceding storm. The weight and density of the atmosphere were here both greater than farther west. As you proceed westward, the wind moderates, becomes calm at many places, and in the central parts of the United States begins to set towards the west. Throughout the Mississippi valley the winds are neither very strong nor uniform in their directions;—a result to be expected, as there was no where any very considerable disturbance of mean temperature or pressure.

Chart 2 represents the features of the storm more fully developed. The snow has increased, dissolving into rain on its southern border; the cloudiness is still farther extended; the blue sky is mostly supplanted. In the eastern states, the pressure of the atmosphere has risen .4 inches above the mean under the influence of the westerly wind; and in the west, the barometer has fallen .4 inches under the influence of the storm. The temperature is generally near the mean, except in the east, where the thermometer is still 10° below the average. The winds are becoming more uniform and steady. Throughout a circle of nearly a thousand miles diameter, the prevalent tendency of the winds is inward towards the storm, with a slight disposition to circulate around this centre against the sun. By the morning of February 16, the storm had made sensible progress towards the east, and become much elongated. The greatest depression of the barometer in the centre of the storm is now .6 inches, and increases in each direction, standing .2 inches above the mean on the front of the storm. Here, also, the thermometer stands at its mean height; while, a little in advance of the centre, it stands 5° above the mean; a little behind the centre it stands at the mean, and in the rear 10° below the mean. The same law as just stated, holds true with regard to the winds. There is a prevalent tendency inward, with a disposition to circulate around the centre.

Chart 4 shows the storm still farther advanced. The area of rain is now nearly equal to that of the snow. The cloudiness in the rear of the storm is contracted into narrow limits, and blue sky covers nearly the entire United States. The barometer in the centre of the storm now stands .8 inch below the mean. It stands near the mean in the rear of the storm, and evidently as high and perhaps higher on the front. The thermometer near the middle of the storm stands 10° above the mean, and in the rear 20° below. The winds are now generally very strong and steady, exhibiting in a still more striking manner the phenomenon already alluded to, that of an inward tendency, with a disposition to circulate around the centre in a direction contrary to the sun's motion. On the morning of the 17th, only a part of the storm is included within the limits of the United States, and the observations are confined to one side of its centre, which is much to be regretted, as its violence was still increasing. The barometer stands 1.00 inch below the mean in the middle of the storm, and at the mean in the rear. The thermometer stands 20° above the mean in the middle of the storm, and 20° below the mean on the rear. The same law of the winds holds true. In the north-western part of the United States, cloudiness was commencing, which was followed by another storm about equally remarkable with the one we are considering. In the following table, column second shows the amount of snow at the different stations, and column third the total amount of water, including snow and rain.

STATION.	SNOW.	WATER.	STATION.	SNOW.	WATER.
	Inches.	Inches.		Inches.	Inches.
St. Louis,	Snow,	0.01	Detroit,	.25	.10
Fort Winnebago,	Snow,	0.4	Fort Gratiot,	Snow,	.06
Indianapolis,		0.018	Marietta,	1.5	
Cincinnati, (Ray,)	4.75	0.51	Hudson,		0.30
" (Williams,)	6	0.51	Ravenna,	5	
Fort Brady,	1.5		Meadville,	2	
Columbus,	5		Erie,	2	.167

STATION.	SNOW.	WATER.	STATION.	SNOW.	WATER.
	Inches.	Inches.		Inches.	Inches.
Pittsburgh,	2		Philada., (Evans,)		.873
Alleghany Arsenal,		.15	" (Conrad,)	Snow and Rain.	.900
Butler,	2		Newtown,	1	1.160
Fort Niagara,		.20	Malone,		1.16
Somerset,	3.5		N.Y.City, (Jortin,)		.58
Lockport,	8		" (Fort Col.,)		.30
Millville,		.12	" (Fort Wood,)		.55
Winchester, Va.,	6.5		West Point,		.90
Huntingdon,	3.5		Albany,	Snow and Rain.	1.12
Rochester,	4 or 5		Watervliet Arsen.,	6	.36
Bellefonte,	2.5		North Salem,	Mostly Rain.	1.50
Gettysburgh,	10.5		Plattsburgh,		.30
Carlisle,		.833	Montpelier, Vt.,	18	
Washington City,		.60	Grafton, Vermont,	10	
Northumberland,	11		Amherst,	1	.60
Fort M'Henry,		.70	Hanover,	7	.80
Harrisburgh,	11		Worcester,		1.31
Fort Monroe,		.60	Fort Adams,		.93
Lancaster,	7	.675	Cambridge,		.855
Port Carbon,	11		New Bedford,		.76
Madison Barracks,		.20	Fort Constitution,		.50
Sackett's Harbour,		.20	Fort Preble,		.90
Casenovia,	20	1.80	Gardiner,	3	.69
West Chester,		1.15	Charleston, Me.,	6	
Haverford,	1		Fort Kent,	24	
Utica,	12		Hancock Barracks,		.53
			Fort Sullivan,		.15

From this table it will be seen that, in the extreme western states, but little snow fell; in Ohio, the average was not quite half an inch of water; in the interior of Pennsylvania and New York, about three quarters of an inch; and farther east, the average was about an inch:—amounting, on the northern border of Maine, to two feet of snow.

The following table contains all the stations where the direction of the clouds was recorded.

	February 15.			*February* 16.			*February* 17.		
Cincinnati,	W.		W.	W.N.W.			Clear.		
Hudson,	Clear.		W.S.W.	N.W.		N.N.W.	W.N.W.		W.S.W.
Meadville,				S.W.					
Erie,		W.				W.	W.N.W.		
Pittsburgh,				N.E.	N.W.	N.	N.N.W.		N.W.
Franklin,	Clear.	Clear.	S.E.	S.E.	S.E.	N.W.	N.W.	N.W.	Clear.
Union,		S.W.	S.W.	W.	W.	N.W.	W.		S.W.
Toronto,	W.	W.	N.W.	W.	N.W.	N.W.	N.	N.W.	N.W.
Bedford,		W.	S.	S.W.	N.W.	N.W.	N.W.	N.W.	
Bellefonte,	N.					N.	N.	N.	
Mifflintown,	N.W.					N.W.	N.W.	N.W.	
Gettysburgh,		W.	W.				N.W.		
Carlisle,	W.			E.			N.W.	N.W.	N.W.
Northumberland,	N.W.	W.	W.				N.W.	N.W.	
Port Carbon,	N.W.	W.						N.W.	
Lancaster,	N.N.W.	N.W.							
West Chester,							W.	W.	
Haverford,	N.W.	N.W.			S.W.		N.W.	N.W.	
Philadelphia,	N.W.	W.	S.W.	S.E.	S.E.	W.N.W.	W.	W.	
New York,	N.N.W.		W.N.W.	S.S.E.	E.S.E.	S.	{W.S.W. W.N.W.}		
Middletown,	N.N.W.		N.W.	S.		S.	W.		W.N.W.
Amherst,				S.E.		S.E.			N.W.

The following table, showing the difference between the dew point and the external temperature at Hudson, will enable us to form some estimate of the lower limit of the clouds.

	Comp. Temp. dew point.	Height of Clouds.	Winds.	Clouds.
Feb. 15, 9 A. M.	4° 0′	400 Yards.	W. by S.	None.
" " 3 P. M.	17 2	1720	S. S. E.	W. S. W.
" 16, 9 A. M.	7	70	W. N. W.	N. W.
" " 3 P. M.	5 4	540	N. W. by N.	N. N. W.
" 17, 9 A. M.	7 8	780	W.	W. N. W.
" " 3 P. M.	12 3	1230	S. W. by S.	W. S. W.

The clouds were invariably from the west, and the winds generally so, but on the fifteenth, when the wind was easterly, the clouds at the height of a mile were from west-south-west.

Before commencing the inquiry into the causes of the phenomena of this storm, I propose briefly to review the phenomena of the storm of February 3.

Storm of February 3, 1842.

The most important features of this storm will be seen from the accompanying charts, numbers 6 to 13. I have called it one storm, though, perhaps, with more propriety, it might be called several; for it is obvious that there was more than one centre of action. On the first of February, at sunset, the storm was marshalling its forces. No rain had fallen, but clouds had formed in four different places, as seen by chart 6, in the north-east, north-west, south-east, and south-west parts of the United States, respectively. The chief of these was in the south-west, and from this, during the succeeding night, was discharged a torrent of rain. Chart 7 shows the condition of the storm the next morning. The north-east cloud had greatly expanded, but had yielded no rain. The north-west and south-east clouds had deposited a little rain; but the south-west cloud had poured down rain over a circle at least seven hundred miles in diameter. Before sunset of the second, the north-east cloud had expanded still farther, but without rain. The south-east cloud had ceased to rain; the north-west cloud had become blended with the south-west, and rain was now falling over an area about one thousand miles long by five hundred broad. Before morning of the third, rain burst forth in torrents from the north-east cloud, and united with the south-west, so that the area of rain was, at least, seventeen hundred miles long, from south-west to north-east, and in its greatest breadth at least nine hundred miles. Upon the northern margin of the storm was a band of snow. Before sunset, this storm became broken into three considerable portions; the south-west being the largest. The clouds became somewhat broken, and in the north-east the rain was generally moderate, amounting, in many places, to a mere drizzle, and at others bringing a dense fog. Before the morning of the fourth, the storm became still farther broken into five small patches of rain, with numerous openings through which clear sky

could be seen. By sunset, one of these patches of rain had assumed a very regular figure. It was about three hundred and sixty miles by two hundred and eighty, and lay directly over lake Erie, being fringed with snow upon its northern border. Near the middle of this ellipse, occurred a remarkable tornado, of which an account is given in the American Journal, Volume xliii., page 278. The clouds were much more broken than in the morning. By sunrise of the fifth, the whole was driven into the north-east corner of the United States.

The following table shows the amount of rain during the entire continuance of the storm, for the western, middle, and eastern parts of the United States.

WESTERN.		MIDDLE.		EASTERN.	
Fort Towson,	4.70	Hudson,	2.277	Hanover,	1.68
Fort Jesup,	4.11	Meadville,	2.128	Watervliet Arsenal,	1.40
Nashville,	3.85	Casenovia,	1.99	Gardiner,	1.32
Natchez,	3.56	Ebensburgh,	1.856	Fort Sullivan,	1.25
Fort Smith,	3.40	Marietta,	1.75	Williamstown,	1.23
Cincinnati, (Williams,)	2.99	Erie,	1.675	Fort Preble,	1.2
" (Ray,)	2.57	Fort Niagara,	1.60	Fort Adams,	1.07
Vicksburgh,	2.91	Pittsburgh,	1.52	Albany,	1.03
Cedar Keys,	2.10	" (Arsenal,)	1.51	Providence,	.88
Louisville,	2.09	Bellefonte,	1.501	North Salem,	.80
Portsmouth, Ohio,	2.00	Butler,	1.445	Malone,	.75
Detroit, (Duffield,)	1.681	Franklin, Penna.,	1.3	Amherst,	.71
" (U. S.,)	1.00	Fort Monroe,	1.2	New Bedford,	.70
New Orleans,	1.15	Huntingdon,	1.017	Hancock Barracks,	.70
" "	1.1	Northumberland,	.992	Plattsburgh,	.60
Fort Brady,	1.0	Rochester,	.99	West Point,	.60
Dearbornville,	.90	Millville,	.98	Worcester,	.60
Fort Gratiot,	.80	Port Carbon,	.933	Haverford,	.523
St. Louis,	.72	Madison Barracks,	.90	New York,	.51
Jefferson Barracks,	.40	Somerset,	.88	" (Fort Col.,)	.50
Fort Gibson,	.30	Washington City,	.708	" (Fort Wood,)	.09
Fort Winnebago,	.10	Savannah,	.480	Cambridge,	.371
Fort Leavenworth,	.00	Gettysburgh,	.285	Fort Constitution,	.33
Fort Crawford,	.00	Carlisle,	.283	Philadelphia,	.30
		Mifflintown,	.120	" (Conrad,)	.286
		Lancaster,	.10	West Chester,	.26
				Newtown,	.190

Thus it appears that, in the south-west, there was a considerable area over which the fall of rain must have averaged three inches; in the vicinity of Ohio, probably throughout the entire state, two inches fell; while throughout a considerable part of New England the fall averaged about one inch. It rained in the south-west about forty-two hours. At Hudson, from the beginning to the end of the rain was a little more than two days; it rained steadily about thirty-five hours. At Hanover, it rained about twenty-four hours, but from the beginning to the end of the rain was fifty-one hours.

The following table contains all the stations where the direction of the clouds was recorded.

	February 1.		*February* 2.			*February* 3.			*February* 4.			*Feb.* 5.
Cincinnati,		W.	S. W.		S.W.	S. W.		S. W.	S.		W.	W. S.W.
Hudson,		W.N.W.	W.		S. S. W.	S. W.		W. S.W.	S.E. rain.		S.	W.N.W.
Meadville,		W.				S.	S.			S.		W.N.W.
Erie,					W.	W.S.W.		W.S.W.	W. E.N.E.	W.	W.S.W.	N.W.
Pittsburgh,	S. W.			S.W.		S. W.		W. S.W.		S. E.		N.W.
Franklin,											S. E.	N.W.
Union,			S. W.		S. W.	S. W.		S. W.	S. W.		S. W.	N.W.
Toronto,		W.	W.		W.	S. W.		W.	W.	S.E. rain.	E. rain.	N.W.
Bedford,			N. W.		S. W.	S. W.		S. W.	S. W.		S. W.	N.W.
Bellefonte,	W.					W.	W.					W.
Mifflintown,						S. W.	S.W.		S. W.		W.	N.W.
Gettysburgh,			W.		W.		S.	S. S.W.	S. S.W.	S. W.		W.
Carlisle,	N. W.			W.		S. W.		S. W.	S. W.		W.	N.W.
Northumberland,	N. W.		W.		N. W.	S. W.	S.W.		W.	S.		N.W.
Port Carbon,									N.	S.	S. W.	N.W.
Lancaster,			W.						S. W.		S. W.	N.W.
West Chester,		W.	W.		S.	S.		S.	W.		S. W.	W.
Haverford,		W.	N. W.	W.		W. S.W.	W.		S. W.	W.S.W.		N.W.
Philadelphia,			W.	W.		S.	S.W.		S.S. W.		S.	W. S.W.
New York,	N. W.		W.		W.	W. S.W.		W. S.W.	W. W.S.W.		W.	W.
Middletown,		N. N. W.	W.		W.	S. W.		S. W.	W.		W.	W.
Amherst,		N. W.						S. W.	N.W. S.W.			N.W

This table exhibits a remarkable uniformity; the direction being almost invariably from the west. Only six observations in one hundred and forty-six are from the east, and, in one of these cases, higher clouds were seen from the west, and in each of the other cases rain was falling. These observations indicate the direction of the wind in the region of the clouds observed. When rain is falling, the clouds are usually low, and have nearly the direction of the wind at the surface, although a higher current may still be blowing from a different direction. There seems, then, no room to doubt that throughout the entire period of these observations a westerly wind prevailed at a certain elevation from the earth's surface. The following observations of the dew point at Hudson afford some data for judging of this elevation.

	Comp.Temp. dew point.	Height of Clouds.	Direction.
Feb. 1, 3 P. M.	9° 5′	950 Yards.	W. N.W.
" 2, 9 A. M.	8 4	840	W.
" " 3 P. M.	5 4	540	S. S. W.
" 3, 9 A. M.	1 0	100	S. W.
" " 3 P. M.	4 0	400	W. S.W.
" 4, 9 A. M.	0 0	000	S. E.
" " 3 P. M.	5 6	560	S.
" 5, 9 A. M.	1 2	120	W. N.W.

It will be perceived that these clouds were all quite low, the highest southerly cloud being a third of a mile in elevation. It is inferred that at an elevation of a mile or so, the winds were invariably from some western quarter.

With this general review of the *facts* respecting these two storms, let us proceed to a more particular consideration of their causes.

I. OSCILLATION OF THE THERMOMETER.

Both of these storms, as well as that of December 20, 1836, were accompanied by a considerable elevation of the thermometer. Under this last storm, the thermometer rose 20° above its mean height; February 17, 1842, it rose the same; and February 4, 1842, it rose 30° above the mean. What is the cause of this extraordinary temperature? The three following causes may be supposed to contribute to the effect.

1. Diminished radiation, in consequence of the sky being covered with clouds.
2. The heat evolved in the condensation of vapour.
3. The transfer of air from a more southern latitude.

The first of these causes can have but a limited influence. We may estimate the amount by comparing the means of observations made in clear and cloudy weather. The observations on the accompanying charts correspond about to the hours of sunrise and sunset. The following results I have deduced from observations made by Mr. Bond, at Cambridge. Column first shows the mean temperature, at sunrise, when the cloudiness was less than five tenths; column second, the temperature of the rest of the month.

	CLEAR.	CLOUDY.	DIFF.
December, 1841,	21°.4	30°.1	8°.7
January, 1842,	16 .6	30 .8	14 .2
February, 1842,	20 .4	31 .2	10 .8
Mean, ...			11 .8

According to these observations, in the winter, at Cambridge, the thermometer for clear mornings, stands 5°.9 below the mean, and on cloudy mornings the same above. We may estimate the effect of radiation then, at 5°. We have still to be accounted for, an elevation of 15° in two storms, and of 25° in the other. Can this be ascribed to the heat evolved in the condensation of vapour? The heat evolved in the precipitation of one inch of water, is sufficient to raise the temperature of the surrounding atmosphere about ten degrees. The fall of water, in these storms, was very great. Does not this explain the whole rise of the thermometer? I infer not, for the following reasons:

1. The rise of the thermometer was not proportioned to the amount of rain. Thus in the storm of February 4, the rain averaged three inches for a large area in the south-west; in Ohio, about two inches; in New England, one inch. The greatest rise of the thermometer in the south-west, was 20°, and in New England, 30°.

2. In tropical countries, where the range of the thermometer is least, the fall of rain is the greatest. Thus at Singapore, latitude 1° 20′ north, according to a register published in Silliman's Journal, Volume xliv., page 151, the entire range of the thermometer for sixteen months was 21°.3, while the fall of rain for one year was ninety-three inches. At Bombay, the average fall of rain for June is twenty-four inches, and the same for July. More than twice this quantity has repeatedly fallen in one month. June 23, 1817, 9.03 inches of water fell, and on the next day, in a period of nine hours, 7.23 inches fell, yet the entire range of the thermometer, for the month, was only 12°, and the thermome-

ter at no time rose 7° above the mean. According to the reports of the British Association for 1839, page 15, on the Ghâts of Western India, there fell, in 1834, 302 inches of rain, (= 25 feet,) of which 118 fell in July, while the mean variation of temperature for the month was only *three* degrees! These extraordinary rains seem rather to cool than heat the atmosphere at the surface.

3. The reason of this last remark will appear from observations of the temperature of the fallen water. According to observations at Cuba, published in Silliman's Journal, Volume xxxi., page 289, the mean temperature of falling rain water, was more than eight degrees below the mean temperature of the locality. The reason is obvious. The precipitation takes place at a great elevation, and the water descends with the temperature of that region. This cold shower, mingling with the air at the surface, lowers its temperature, or prevents that elevation of temperature which might be expected from the heat liberated in the condensation of the vapour. I do not see, then, how we can ascribe any considerable part of the effect in question to the heat of the condensed vapour. Can it, then, be ascribed wholly to a change of latitude of the wind? On the Atlantic coast, in winter, the change of temperature is 15° for 10° of latitude. In the interior the change of temperature is greater. Thus,

Temperature of Fort Churchill,	latitude	58° 57′	north, in winter is	20°.23.
" " Hudson,	"	41 15	" "	27 .68
		17° 42′		47°.91

Or 27°.1 for ten degrees of latitude.

Temperature of Fort Snelling,	latitude	44° 53′	north, in winter is	16°.70.
" " Natchez,	"	31 34	" "	50 .32
		13° 19′		33°.62

Or 25°.2 for ten degrees of latitude.

Over how many degrees of latitude did the wind in question blow? On the morning of February 17, 1842, the thermometer, in Maine, stood 20° above the mean. Allowing five degrees for radiation, we have an effect of 15° to be accounted for. The wind had been blowing from the southward about twenty-four hours, with an average velocity of about forty miles per hour, equal to nine hundred and sixty miles, which probably corresponds to six hundred and seventy-nine miles in the direction of a meridian, or nearly ten degrees of latitude. This wind might, consequently, have come from Bermuda.

The temperature of Bermuda,	latitude	32° 34′	in winter is	59°.11.
" " Eastport,	"	44 54	" "	22 .42
Effect of latitude, ...		12° 20′		36°.69

Or 29°.7 for ten degrees of latitude. This air, then, should have an excess of heat much greater than that actually observed, provided that none was lost in the transfer. We may allow a loss of one half, and still have an excess sufficient to satisfy the observations.

December 21, 1836, the temperature in New England was also 20° above the mean.

The wind had been blowing from the southward about the same time, and with the same force, as February 17.

On the morning of February 2, 1842, the temperature in Arkansas was 20° above the mean. The winds were southerly, and had been so for the preceding day over a considerable district, in which time the wind might have travelled ten degrees of latitude.

Temperature of Havanna, latitude	23° 10′ in winter is	72°.22.
" Natchez, "	31 34 " "	50 .32
Effect of latitude, . . .	8° 24′	21°.90

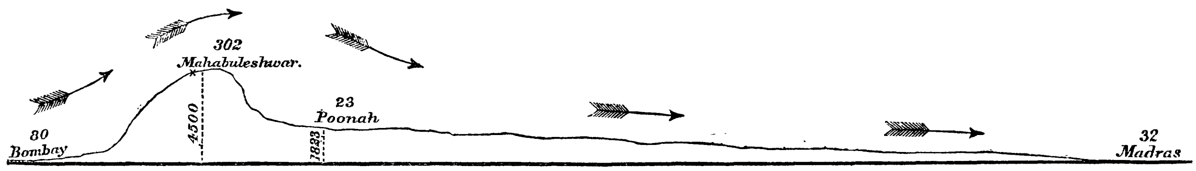
Or 26°.1 for ten degrees of latitude.

We may thus make a liberal allowance for loss of heat in travelling northward, and still explain the whole effect observed. February 3, 1842, in the morning, the thermometer, in the western part of Pennsylvania, stood 30° above the mean; the same in the centre of New York state in the evening; and also throughout the 4th, in the vicinity of Philadelphia. February 3, at Pittsburgh, the wind had been blowing about thirty hours from the southward, in which time it might have travelled 12° of latitude, giving an elevation of about eighteen degrees, which, allowing for the loss of heat in travelling northward, is not more than half enough. Our explanation, then, seems to fail. It should be remembered, however, that in estimating the effect of a particular storm, our standard should be, not the mean temperature of a long period of years, but rather of a few days just preceding the storm. The temperature of January, was, throughout most of the United States, five degrees above the mean. Allowing also, five degrees, for radiation, we have only an effect of twenty degrees to be explained. About half of this effect may be ascribed to simple change of latitude; and when it is remembered that over a large area in the south-west, the thermometer stood 20° above the mean, and that this heated air was transported mostly towards the north-east, we have a cause sufficient to explain the whole effect in question.

To explain the cold which succeeds the storm. After the storm of February 4, the thermometer no where sunk much below the mean. A north-west wind succeeded the storm, yet it was not of long continuance, and its cold was neutralized by the extraordinary elevation of temperature which preceded it. After the storm of February 16, the thermometer generally sunk 20° below the mean. This wind was very strong, and probably travelled full ten degrees of latitude. After the storm of December 20, 1836, the thermometer, in the neighbourhood of the Mississippi, sunk from 30° to 40° below the mean. The entire month of December, 1836, was a little below the mean, but not more than a degree or two. It seems necessary to admit that this current travelled more than fifteen degrees of latitude; a supposition, I think, not inadmissible.

II. CAUSE OF THE RAIN.

We may be guided in our inquiry for the cause of the rain by comparing the circumstances of two extreme cases, where no rain falls and where it falls most abundantly. Such an example we find in India. At Bombay the average fall of rain is eighty inches,



and it falls wholly from June to October, under the south-west monsoon. This wind blows over a range of mountains varying from one thousand to eight thousand feet in height. At Mahabuleshwar, at an elevation of four thousand five hundred feet, the fall of rain, in 1834, was three hundred and two inches, and almost wholly with the south-west monsoon. At Poonah, on the eastern side of the mountains, elevated one thousand eight hundred and twenty-three feet, the annual fall of rain is only twenty-three inches, while, at Madras, it is thirty-two inches. By the interposed range of mountains, the humid air from the ocean is cooled, and the windward slope of the mountain is deluged with rain. The case is quite analogous with a southerly wind in the United States. A south wind from the level of the sea encounters land every where swelling to the height of several hundred feet, and rising in ridges and insulated peaks to the height of four or five thousand feet. A copious precipitation must be the consequence. But it is not wholly by elevation that the rain is caused; the effect is increased by collision with the upper current flowing in a different direction. The winds marked on the charts are merely surface winds; but from the observations, pages 166 and 169, there is reason to believe that the whole upper part of the atmosphere was pursuing its course undisturbed from the south-west or west over the entire United States. Suppose the lower current coincide in direction with the upper: then the whole atmosphere moves on as one mass, there is no mingling of strata of unequal temperature, and no cause for the formation of cloud. Suppose, however, the direction of the lower stratum is changed, while that of the upper continues, then we have two currents rubbing upon each other, generally of unequal temperature, differing also, perhaps, in their amount of moisture. There will be a partial mingling, and, of course, cloud formed. It seems then hardly possible that the lower current should change its direction to a warmer quarter, and continue thus for many hours without the formation of cloud, and followed by the production of rain.

The effect of an elevated ridge of land appears sensible in the difference of climate upon the two sides of the Alleghanies. The region immediately west of that range of mountains has a sensibly greater degree of cloudiness, (particularly in winter,) than places on the east side. This appears from the following table of averages, (0) representing a sky perfectly clear, (10) entirely overcast.

	HUDSON, O.		HANOVER, N.H.			CAMBRIDGE, MASS.			
	9 A. M.	3 P. M.	Sunrise	$1\frac{1}{2}$ P.M.	$9\frac{1}{2}$ P.M.	Sunrise	9 A. M.	3 P. M.	9 P. M.
Spring,	5.70	5.91	3.93	4.02	3.55	5.50	5.80	6.33	5.53
Summer,	5.22	5.57	5.43	3.41	2.92	5.43	5.23	5.33	4.90
Autumn,	5.96	6.20	5.66	4.34	3.54	5.77	5.60	5.93	4.53
Winter,	8.07	7.87	4.65	4.30	4.14	5.20	6.00	5.67	4.80
Year,	6.24	6.39	4.92	4.02	3.54	5.47	5.66	5.81	4.94

The prevalent westerly winds glancing up over the Alleghany ridge deposit a portion of their vapour, forming cloud on the western slope, particularly in winter, when these winds are usually strongest, and the dew point differs least from the temperature of the air. It is thought that the operation of this principle may be traced in the storms of February, 1842. On the fourth, at sunset, the clouds were very much broken, particularly on the east slope of the Alleghanies, while cloud, and in some places rain, still lingered on the west slope. As the westerly wind pours over the mountains and descends to the level of the sea, it comes under greater pressure, and heat is developed, which dis solves the precipitated vapour, producing clear sky. Thus clear sky succeeds a storm much sooner on the eastern than on the western side of the mountains. The same is seen at sunset on the sixteenth, the clear sky advancing with great rapidity on the southern border of the storm.

I do not regard the configuration of the earth's surface as the main cause of storms in the United States, but only as an auxiliary and modifying cause. The same effect which is produced by an interposed mountain is produced by the apposition of surface winds, by which means a mass of air is elevated into a region of greater cold.

III. THE MOTIONS OF THE WIND.

That an easterly wind should spring up on the morning of February 15, in the region of Ohio, was the necessary result of the greater weight and density of the air to the eastward. But a westerly wind, at the same time, prevailed a little beyond the Mississippi river. These two winds were partially opposed, and from this opposition the air between them was elevated somewhat above the surface of the earth. Being cooled by diminished pressure, its vapour is condensed, a portion of it falls as snow, and the remainder forms cloud which expands and covers the surrounding country. The condensation of the first vapour developed heat, which diminished the specific gravity of the surrounding air, thereby causing a more decided tendency towards the storm, which increased the precipitation and the development of heat, so that the storm increased in violence as it continued. In the region of the greatest condensation, the rise of temperature was probably greater than at the surface of the earth. As the result of this rarefaction, the air swells up above its usual height, and flows off in every direction, carrying with it the cloud already formed, and causing the barometer to fall steadily as the storm continues to rage. Let us examine particularly the case of a body of air, from the earth's surface, forced up to a considerable elevation.

According to Poisson, "Nous manquons des données nécessaires pour la solution complète de ce problême;" nevertheless, I propose to inquire to what extent the problem is undetermined. Gay Lussac, in his aeronautic ascent to the height of twenty-three thousand feet, found the thermometer fall 1° F. for three hundred and seventeen feet elevation. According to Professor Forbes, the mean decrease, in Europe, is 1° for three hundred and fifty-two feet; according to Pouillet, three hundred and sixty-four feet in the equatorial regions, and three hundred and nineteen in Europe; according to Lubbock, 1° for three hundred and forty feet. If we assume 1° for three hundred and thirty feet, we cannot be far from the truth. According to Leslie, the heat liberated, when air has its density

doubled, is $67\frac{1}{2}°$ F., and the same quantity is withdrawn when air of the ordinary state expands into double its volume. According to the experiments of Desormes and Clement, the heat is greater than this. When we consider the extreme mobility of the atmosphere, it can hardly be doubted that the cold of expansion is almost identically that which prevails ordinarily in the higher regions of the atmosphere, and that, when vapour is condensed by the cold of diminished pressure, the heat evolved raises the temperature of the surrounding air above that which is proper to this height, and it is thus elevated still farther by its own buoyancy.

In some parts of the Arctic regions, clouds are almost unknown in the winter. The reason is obvious. The temperature is constantly below zero, and the tension of vapour can seldom rise as high as 0.068. If all this vapour should be condensed, it would raise the temperature of the air only 7°; so that if air from the earth's surface could be mechanically elevated to a great height, its temperature, notwithstanding the condensed vapour, could hardly exceed, perhaps not equal, that of the surrounding air. Hence there is little opportunity for ascending currents, and consequently no cloud.

Let us begin with the first formation of cloud on the western border of the United States, which happened a little before sunrise of February 15. The heat liberated in the formation of this cloud raises the thermometer, causing a more decided tendency of the air inward towards the region of condensation. The whole heavens being covered with a veil, radiation from the earth's surface is checked, while it is going on beyond the region of the cloud. This causes a relative elevation of temperature under the cloud, and gives increased velocity to the inward current of air. More cloud is thus formed, heat is liberated: the air, expanded, swells up beyond its usual limits, and flows over in every direction, carrying with it the snow formed, which, while suspended in the air, appears merely as cloud, causing the barometer to fall gradually in the centre of the storm. Thus the storm gains violence by its own action, and being floated eastward by the prevalent westerly current, it ceases in the western states, while it is still raging with increased violence in the east. The winds might then be expected to flow inward towards the centre of the storm. As, however, the storm covers a large area and is somewhat irregular in shape, the winds could not all blow towards one point. Moreover, such a central tendency, whether in air or water, uniformly causes the fluid to approach the centre, not exactly in radii, but circuitously. This effect can hardly be detected on the chart for the fifteenth, at sunrise, but at sunset a slight tendency may be perceived, to circulate against the sun. On the sixteenth, at sunrise, the phenomenon is more strongly marked, and at sunset it is impossible to overlook it. There is a physical cause for this rotation, and for its being uniform in direction, in the case of large storms. The southerly wind has a greater motion eastward than the parallels upon which it successively arrives, arising from the rotation of the earth; and the northerly wind a less motion eastward, or a relative motion westward. Hence in this region the circulation, in great storms, is probably invariable in direction.

On the chart of February 15, at sunset, we see in a striking light, the effect of the upper current. The condensed vapour as it rose spread out in every direction, but only slightly westward, while eastward it extended nearly four hundred miles in advance of the snow. On the southern border, the temperature is such as to melt the flakes of

snow as they fall, producing rain; and as the heat of the storm increases, the breadth of the rain increases to beyond the limits of the United States, and this, although the storm was continually advancing to a higher latitude. As the storm continued, the north-west wind which succeeded it set in with increased violence towards this region of rarefaction, producing a sudden depression of the thermometer, amounting to more than twenty degrees below the mean.

Two questions here naturally arise. First, What caused the formation of the first cloud on the morning of the fifteenth? and secondly, Why should the storm once organized ever cease? This first cloud I ascribe to the superior weight and density of the air in the central parts of the United States. This superior weight was the result of a storm experienced in the same region two days previous, the margin of which is seen upon the extreme east border of chart 1. So also the low temperature which succeeded the present storm, as exhibited in chart 5, produced a similar easterly wind, causing a cloud which is seen upon the extreme left of the chart, which grew into a storm of nearly equal violence with that we are now considering. Thus, one storm begets its successor. The undulations thus excited in the atmosphere bear considerable analogy to the waves of the ocean agitated by a tempest, and which are propagated by mechanical laws long after the first exciting cause has ceased to act.

Secondly, It may be thought, if the explanations here given are well founded, that when a storm is once organized it should go on increasing in violence, and never cease raining while there was vapour to be precipitated. By inspecting the annexed charts, I think we shall see a principle in operation which must prevent any considerable further increase of violence, and soon cause it to decline. On chart 3, the line of $-20°$ is distant about seven hundred miles from that of $+5°$; on chart 4, it is distant only five hundred miles from that of $+10°$; and on chart 5, it is less than five hundred miles from the line of $+20°$. The line of mean temperature is only one hundred and sixty miles from that of $+20°$. This cold north-west wave advanced more rapidly than the centre of the storm. It was beginning to counteract the increase of temperature arising from the condensed vapour, and after that the violence of the storm must rapidly decline.

Let us now turn to the storm of February 4. Beginning with February 1, sunset, we find the barometer at its mean height near the valley of the Mississippi, and .3 inch above the mean in the vicinity of New York. The thermometer stood 10° above the mean near the Mississippi, while farther east it stood at the mean. For both of these reasons there should be an easterly wind near the Mississippi. This easterly wind encountering the prevalent westerly wind beyond the United States, which is seen on the chart the next morning, is lifted from the surface and a portion of its vapour is condensed, forming cloud. This is the origin of the two clouds near the Mississippi. No great elevation is requisite to produce this effect. Although the dew point at the earth's surface may be low, there is always a point, not very elevated, where the air is saturated with vapour. Any increased elevation of this stratum will cause a precipitation of moisture. Cloud being once formed in considerable quantity, contains within itself the principle of rain. The easterly winds become more general and strong, and the precipitated vapour soon reaches the earth in the form of rain. In the eastern states the winds were strong from the north-west, the result of the storm which had prevailed the day previous.

Between these easterly and westerly winds we find a region of calms marked on the chart. The formation of the north-east cloud I suppose to be as follows. The pressure of the atmosphere was greater near the Atlantic than towards Lake Ontario. This must give a check to the north-west wind from the lake, causing a part of it to glance upward, forming cloud. The probability of this explanation will be seen from chart 7, where the cloud is much extended, and the winds are generally blowing from the south. The same causes produced a north-east wind on the south-east border of the United States, which, being opposed to wind from the gulf, formed cloud. By the morning of the second, these clouds were all partially united. The south-west pours down rain. The winds are generally westward on the west border, and eastward on the east border. The thermometer has risen a little, and the barometer fallen .2 inch. No sudden fall could be expected, considering the great extent of the storm. The north-west cloud seems almost to have lost its distinct existence; but in the north-east the winds are blowing from the region of greatest pressure, and cold towards the cloud. The south-east cloud had already deposited a little rain. The barometer, in New England, continued to rise, notwithstanding the drain of air by the southerly winds. The air over the St. Lawrence being expanded, swelled up, overflowing New England, and more than compensating for the drain of the lower current. At sunset we find the same causes in operation. The barometer had fallen .6 inch below the mean in the valley of the Mississippi, and this may be regarded as the principal centre of the storm. The winds are now southerly throughout almost the entire United States. The cloud along the valley of the St. Lawrence was now greatly expanded, and ready to pour down rain. Its temperature had risen 20° above the mean. The winds on the south were blowing directly towards it, and probably also on the north. It might be expected that the winds would blow from every quarter towards the barometric minimum near St. Louis. In point of fact, the south-east winds extended much farther north. No doubt, however, north-west winds prevailed at a considerable distance northward, and they showed themselves with great force within the United States on the morning of the fourth. But the storm evidently extended in a north-west direction much beyond the limits of the United States, and the irregularities of the wind are owing to the fact, that the pressure and temperature were so nearly uniform over so large a territory. On the morning of the third the north-east cloud had discharged its contents. The reason that this rain was so long in falling, (more than a day from the first formation of the cloud,) probably was, that the condensed vapour was frozen and the cloud was one mass of snow. The heat liberated by the continued condensation and by the transfer of air from a lower latitude, in time melted it, and it fell in a general deluge. The diminution of pressure in the vicinity of Lake Erie is now quite noticeable, being .6 inch below the mean, and the temperature has risen 30° above the mean; so that this is now the principal centre of the storm, and the north winds are now showing themselves at Montreal and Fort Kent. By sunset of the third, the clouds had become somewhat broken, and the rain had entirely ceased at some places, while it was reduced to a mere drizzle at others. We now see a general tendency of the wind inward from all the borders of the United States. On the south border the winds are, without exception, from the south; on the south-west they are from the west, and on the north border they are from the north. This is a necessary consequence of the elevated tempe-

rature and diminished pressure within the United States, and we can only account for the long delay of this inward rush, by supposing that a similar state of things prevailed far to the north of the United States. To know the full extent of this storm, we need observations far more extensive than I have been able to obtain. The storm is now sure to be contracted within narrower limits. On the morning of the fourth, the rain was very much reduced, and two very distinct centres of diminished pressure are shown, one near Boston and the other near St. Louis. Near Boston the pressure is at a minimum, and the temperature at a maximum, and there is a tendency of the winds inward, with a disposition to circulate against the sun. Thus in the vicinity of the North river, the winds are north; along the Sound they are south-west, and at Gardiner in Maine, they are north-east. In the vicinity of St. Louis the same fact is observable. At sunset of the fourth, some indications of subordinate centres of action may be noticed near New York and in New Hampshire; but throughout almost the rest of the United States, the winds are plainly governed by one centre near the middle of Lake Erie. Here the pressure is least, and the winds, taken as a whole, plainly circulate around this centre, with considerable tendency inward. Thus on the north side the winds are north-east; on the west side, generally north-west; on the south side, west and south-west; and on the east side, generally east, except towards New England, where there are to be seen other centres of action. Here, in the centre of this ellipse, was formed a violent tornado, exhibiting features very similar to those already described; namely, an inward motion of the air, and a circulation against the sun. The cause of this tornado is now obvious. Although its effects were mainly local, its origin was far otherwise. The centre of this vacuum travelled north 62° 17′ east, eight hundred and sixty miles in twenty-four hours, equal to thirty-six miles per hour. The tornado in question travelled north 33° 30′ east, and if we suppose it to have kept pace with the vacuum, the velocity of the tornado must have been forty-one statute miles per hour, a result a little greater than I have given in my published account of the tornado, derived, however, from a much less number of observations.

On the morning of the fifth, the storm was driven into the north-east corner of the United States, but exhibited features very similar to those of the previous evening.

IV. OSCILLATION OF THE BAROMETER.

Local changes in the density of the atmosphere seem to be the chief cause of the oscillations of the barometer; nevertheless these oscillations are propagated by the laws of waves, and are felt much beyond the limits of the original disturbing cause. As this is a very important principle, I propose to adduce conclusive evidence of it. This principle, then, is shown by the fact, that the barometric depression, of which the storm is the centre, often extends beyond the limits of the storm. Thus February 3 and 4, there was considerable depression of the barometer south of the region of rain, or even cloud. This phenomenon must be still more striking in higher latitudes. Thus at Melville island, Captain Parry found the sky generally clear. Though it was sometimes overcast or obscured by a slight general haziness, there were no separate clouds. Some well defined clouds appeared on the sixteenth of April, which were nearly the first that had

been seen. There would seem to be here very little cause for any oscillation of the barometer, and it is probable that if the entire surface of the globe were in the same situation, the variations of pressure would not exceed a small fraction of an inch. The range of the barometer observed at Melville island, December, 1819, was 1.65 inch; January, 1820, 1.18 inch; February, .83 inch; range for the winter months, 1.67 inches, which is equal to the extreme range which has been observed in Hudson in a period of five years. There can be little doubt that these oscillations are mainly the effect of storms prevailing in lower latitudes.

The storm of February 4 was quite extraordinary—for its extent, amount of rain, and long continued elevated temperature; nevertheless it is presumed, in its main features, to resemble our ordinary January thaws.

There was another phenomenon incidentally connected with the storm of February 16, which deserves a passing notice. Halos were observed at several places, during the period in question. The following are some of the observations.

Washington city, February 15, from 6 hours 15 minutes to 8 hours P. M., a perfect lunar halo.

Detroit, February 15, 10 A. M., halo round the sun.

Detroit, February 16, 10 A. M., halo round the sun.

Detroit, February 17, 8 to 10 P. M., halo round the moon.

Toronto, February 16, 8 P. M., imperfect halo round the moon, diameter about 35°.

Fort Gratiot, February 17, halo round the moon.

Hudson, February 17, evening, halo observed.

Fort Constitution, February 17, P. M., parhelion.

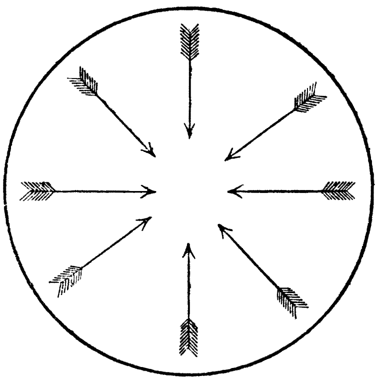
The halos observed on the fifteenth, at Detroit and Washington, were formed in that cloud which is represented on chart 2, which at first was a mere haze, and gradually thickened. February 16, another halo was formed at Detroit and Toronto, in the cloud which followed the storm; and on the seventeenth, a halo was noticed at three places together with a parhelion. If any doubt previously existed as to the cause of this phenomenon, the facts which have already been presented may serve to dissipate it. The argument may be thus stated. A halo of 22° radius would be formed by the refraction of the light of the sun or moon through prisms of ice, having angles of 60° and floating irregularly in the atmosphere. The halo is proved to be formed by refraction. Snow consists chiefly of spiculæ having angles of 60°. Flakes of snow were floating in the atmosphere, February 15, over Detroit and Washington. The halos observed were, therefore, formed by light refracted through these prisms.

GENERALIZATIONS.

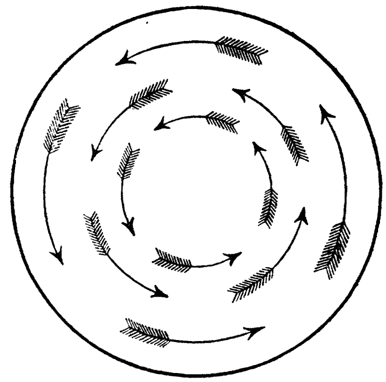
I. DIRECTION OF THE WIND.

The question which has, within a few years, excited most interest in Meteorology, is, whether storms are rotary or centripetal, and it has been supposed that either diagram, No. 1 or No. 2, must represent the motion of the wind.

No. 1.

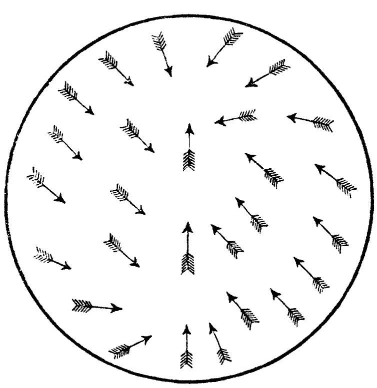


No. 2.

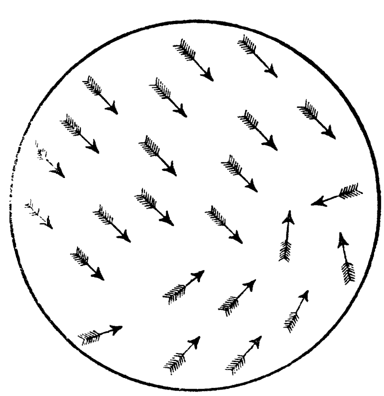


The accompanying charts will show that neither of these diagrams faithfully represents the storms here investigated, and it is doubtful whether either of them ever accurately represents the motion of the wind over any large portion of the earth's surface. The storm of December 15, 1839, has been quoted as a strong case of the revolving kind, and if we take only a semicircle of two hundred miles radius on the north-west side of the centre, the correspondence is very good, (see Mr. Redfield's diagram, Philosophical Transactions Volume viii., page 81,) though, even here, most of the arrows are inclined to the circumferences drawn, and, as Mr. Redfield has remarked, the direction is generally *inward* towards the centre of the storm. But if we take the other half of the semicircle, which Mr. Redfield has omitted, the circles are not completed. There have been several cases, of limited extent, in which the winds might be represented by figure No. 1.; but I have seen no account of a storm, of a hundred or more miles in diameter, in which the winds could be faithfully represented by either of the above diagrams. A combination of the two is, however, frequently seen. No. 3 is intended to represent the motions of the

No. 3.



No. 4.



wind February 16, 1842, at sunset, near the centre of the storm. Substantially the same diagram is applicable for the morning of the seventeenth, so far as appears from the observation, and tolerably well for the morning of the sixteenth, although there is here more irregularity, the storm being of larger dimensions and less violent. The lower half of this diagram represents, very faithfully, the observations for the morning of December 21, 1836; and it may be inferred that if observations could be procured from more northern stations, they would show the other half of the diagram. The same figure

represents, pretty accurately, the storm of January 26, 1839, also the great British storm of August 17, 1840, and that of January 6, 1839, except that in the south-west quarter of the latter, the winds were, perhaps, more south-westerly.

Diagram No. 4, represents the storm of March 17, 1838, the north-east wind covering more than half the region of rain and snow. The storm of December 15, 1839, was quite similar to this last, though the north-east wind covered a smaller portion of the storm. In some storms there is a predominance of north-east winds; in others of the south-east; in some north-west, and others south-west winds; but in all we find certain common characteristics, namely, an inward motion, with a tendency to circulate against the sun. These are the ordinary features of those storms which are accompanied by a gust and sudden oscillation of the barometer. The storm of February 3, 1842, can hardly be comprehended under this class. It was so extensive, the motion of the barometer so slow, and the winds moderate on the second and third, that it seems more properly to belong to a distinct class; although on the fourth and fifth, when the winds sprung up with some force, we find the characteristics mentioned above.

II. PROGRESS OF THE STORM.

A second question of some importance is, in what direction and with what velocity does the storm advance? It is not difficult to perceive that the general progress of storms is eastward, but, when we undertake to assign the direction with minute precision, we feel the necessity of a precise definition of the terms "storm," and the "centre of the storm." I define the centre of a storm to be the point of greatest barometric depression. The storm of February 16 travelled, then, from sunrise of the sixteenth to sunrise of the seventeenth, five hundred and sixty statute miles in a direction of about north 53° 18′ east, although to sunset of the sixteenth, its direction had been about north 74° 46′ east. It seems probable that its path was not a straight line, although it is possible that its centre, on the morning of the seventeenth, was farther south than I have here assigned, there being a deficiency of observations on the southern quarter. Velocity twenty-three miles per hour. The storm of February 2 and 3, remained nearly stationary. On the fourth and fifth its progress can be pretty accurately traced. It travelled north 62° 17′ east, eight hundred and sixty miles in twenty-four hours, or thirty-six miles per hour. The direction of the storm of December 20, 1836, cannot be precisely assigned. It was clearly eastward, but having only observations from the southern half of the storm, it is impossible to assign, accurately, the place of greatest barometric depression.

CONCLUSION.

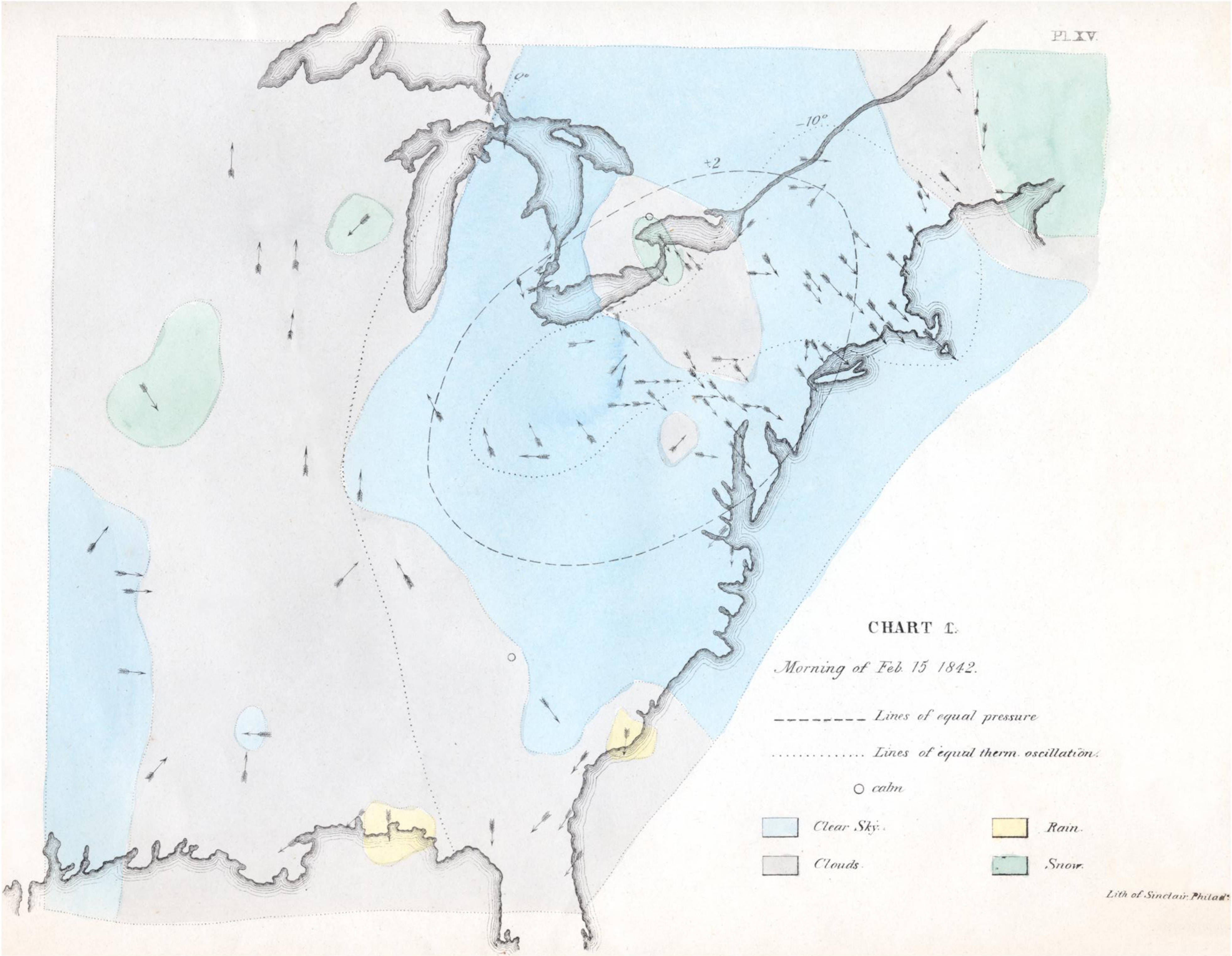
The following, then, is my view of the origin of such storms as I have been investigating. This generalization will probably include the greater part of winter storms, but will require some modification when applied to summer storms. Imagine a time perfectly clear, when the wind is from the west, or a few degrees south of west, with the barometer and thermometer at their mean heights. This may be regarded as the normal state of the atmosphere, and the whole body of air from its upper limit to the surface

of the earth is moving on harmoniously in one direction. How is rain produced in such an atmosphere? The first requisite appears to be a change of direction of the lower stratum of air. This appears, in winter, to be frequently the effect of a preceding storm. The prevalent westerly current being temporarily checked in its progress by a violent storm, soon acquires force sufficient to break down all opposition. It supplants the rarefied air of the storm, and not only restores the barometer to its mean height, but the momentum of the excited mass carries it considerably above the mean. This excess of pressure causes a reverse current a little to the westward of a violent storm; and hence we sometimes have a long series of violent storms succeeding each other, at nearly equal intervals; and hence also a violent storm succeeded by an unusually high barometer affords ground for expecting a second storm within one or two days. But this explanation will not apply to all cases, for then, if the barometer should ever settle down to its mean height all over the globe, we never could have another storm. The case here supposed is not likely ever to happen, but even if it should, we cannot admit the consequences attributed to it. Admit such a case to occur, and the sun's heat would be competent to generate a new storm. Different portions of the earth's surface absorb the sun's rays in unequal degrees, and afford unequal quantities of moisture for evaporation. The result is, that we find bodies of air in close proximity of unequal density, arising from unequal temperature or humidity. Either case would be sufficient to cause a deflection of the lower stratum of air from its normal direction. Suppose, then, we have the mass of the atmosphere pursuing its wonted course from west to east, while a stratum of a mile or so in height, next to the earth's surface, blows in some different direction. If this direction be from the south to the north, then this current must be cooled in its progress by change of latitude. This effect may be aided by the inequalities of the earth's surface, and by friction upon the upper stratum of colder air. At the surface of the earth, where the temperature is probably five or ten degrees above the dew point, no remarkable effect may follow. But at a certain elevation, the air is always saturated with vapour. A very slight reduction of temperature causes cloud, and its density and extent will be proportioned to the energy of the causes in operation. If the wind should blow from the north, it might happen that no cloud would be formed; but if the direction should be easterly, being partly opposed to the normal current, some portion of this mass would almost necessarily be elevated from the earth's surface, and being cooled, its vapour be condensed. The first stage of the process, then, is an abnormal current at the earth's surface; the second is the production of cloud. At this stage the sky is covered with a veil which checks radiation; the thermometer rises above the mean from this cause, and also from the heat liberated in the condensation. This only adds to the energy of the first abnormal current. More cloud is thus formed, and presently the particles of water having acquired sufficient size, fall rapidly to the earth. The wind being southerly, the thermometer rises. A portion of the atmosphere being thus unusually heated and loaded with vapour, while the upper limit of the atmosphere remains nearly invariable, the barometer necessarily falls. Thus, these causes might continue to operate a long time, acquiring energy by their own action. A limit, however, is soon attained. The rarefaction thus produced creates a tendency in the surrounding colder and heavier air, to rush in and occupy its place. Moreover, if the wind be at all easterly, as is usually the

case, it partially obstructs the progress of the normal current. This temporary retardation only gives it accumulated energy, and it is soon reinstated with unwonted violence. When the rarefaction is considerable, this rush of air upon the last half of a storm is not generally in the precise direction of the upper current, but more northerly; this air being the denser. Our southerly wind is thus supplanted by a violent north-wester. We have thus a great rarefaction and elevation of the temperature under a south or south-east wind with rain, extending over a large territory. This may be called the third phase of the storm, although it differs from the second only in intensity. There is now a general rush of heavier air to fill this void. This rush is chiefly from the north; but an independent cause, that which imparts direction to the upper current, would give us a west wind. Under these two forces the resulting current is chiefly north-west, but every where upon the borders, the tendency will be inward. The air thus flowing inward towards a central area, forces upwards the warmer air which rises in the middle, and being cooled by elevation, discharges a greater quantity of rain. The currents moving centrally from every point of the compass, interfere with each other, and pursue their routes spirally inward. We have thus a species of rotation, which, in the centre of the storm may have a destructive violence, as at Mayfield, February 4, 1842. This is the fourth phase, and is the case of a violent storm fully organized. This west or north-west wind carries the storm off from a fixed locality, and it is thus transferred successively to points farther and farther east. But this action cannot continue indefinitely. There is a cause in operation which will soon terminate its violence. This westerly wind travels more rapidly than the easterly. The rarefaction at the centre of the storm is a cause which acts equally upon both winds; but the one is opposed to the upper current, and the other nearly coincides with it: hence the one is accelerated, and the other retarded. The result is, that at successive points, farther and farther east, the same storm (after the north-west wind has begun to blow with great violence) has a less duration; the thermometer rises to a less height, the barometer has a smaller oscillation, and thus at a point far eastward, the oscillation becomes nearly extinct, and the only peculiarity observed in the wind is a stronger westerly current succeeding a calm. This is the fifth and final phase of the storm.

It appears to me, that if the course of investigation adopted with respect to the two storms of February, 1842, were systematically pursued, we should soon have some settled principles in meteorology. If we could be furnished with two meteorological charts of the United States, daily, for one year, charts showing the state of the barometer, thermometer, winds, sky, &c., for every part of the country, it would settle for ever the laws of storms. No false theory could stand against such an array of testimony. Such a set of maps would be worth more than all which has been hitherto done in meteorology. Moreover, the subject would be well nigh exhausted. But one year's observation would be needed; the storms of one year are probably but a repetition of those of the preceding. Instead, then, of the guerilla warfare which has been maintained for centuries with indifferent success, although at the expense of great self-devotion on the part of individual chiefs, is it not time to embark in a general meteorological crusade? A well arranged system of

observations spread over the country, would accomplish more in one year, than observations at a few insulated posts, however accurate and complete, continued to the end of time. The United States are favourably situated for such an enterprise. Observations spread over a smaller territory would be inadequate, as they would not show the extent of any large storm. If we take a survey of the entire globe, we shall search in vain for more than one equal area, which could be occupied by the same number of trusty observers. In Europe there is opportunity for a like organization, but with this incumbrance, that it must needs embrace several nations of different languages and governments. The United States, then, afford decidedly the most hopeful field for such an enterprise. Shall we hesitate to embark in it; or shall we grope timidly along, as in former years? There are but few questions of science which can be prosecuted in this country to the same advantage as in Europe. Here is one where the advantage is in our favour. Would it not be wise to devote our main strength to the reduction of this fortress? We need observers spread over the entire country at distances from each other not less than fifty miles. This would require five or six hundred observers for the United States. About half this number of registers are now kept, in one shape or another, and the number, by suitable efforts, might probably be doubled. Supervision is needed to introduce uniformity throughout, and to render some of the registers more complete. Is not such an enterprise worthy of the American Philosophical Society? The general government have, for more than twenty years, done something, and have lately manifested a disposition to do more for this object. If private zeal could be more generally enlisted, the war might soon be ended, and men would cease to ridicule the idea of our being able to predict an approaching storm.



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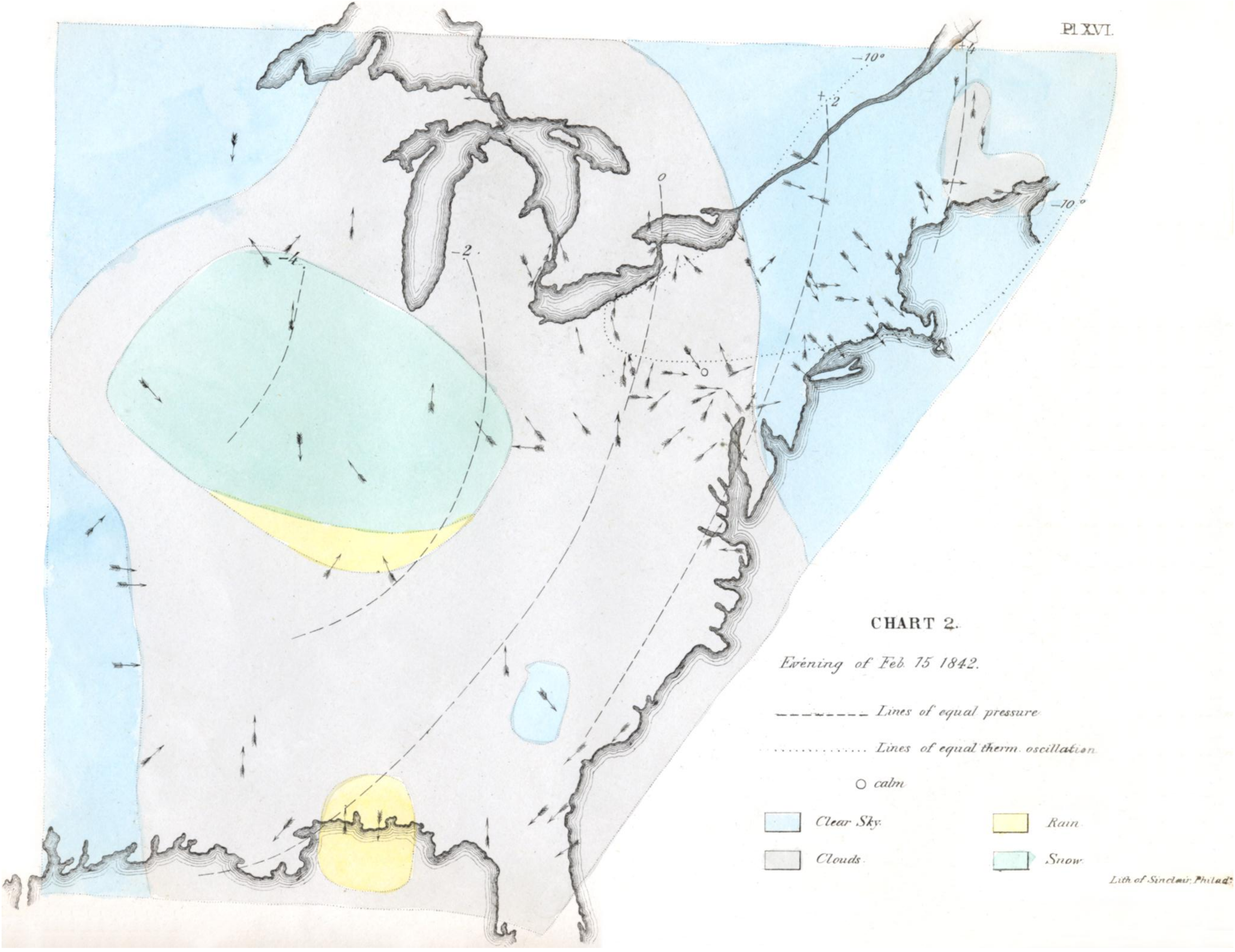

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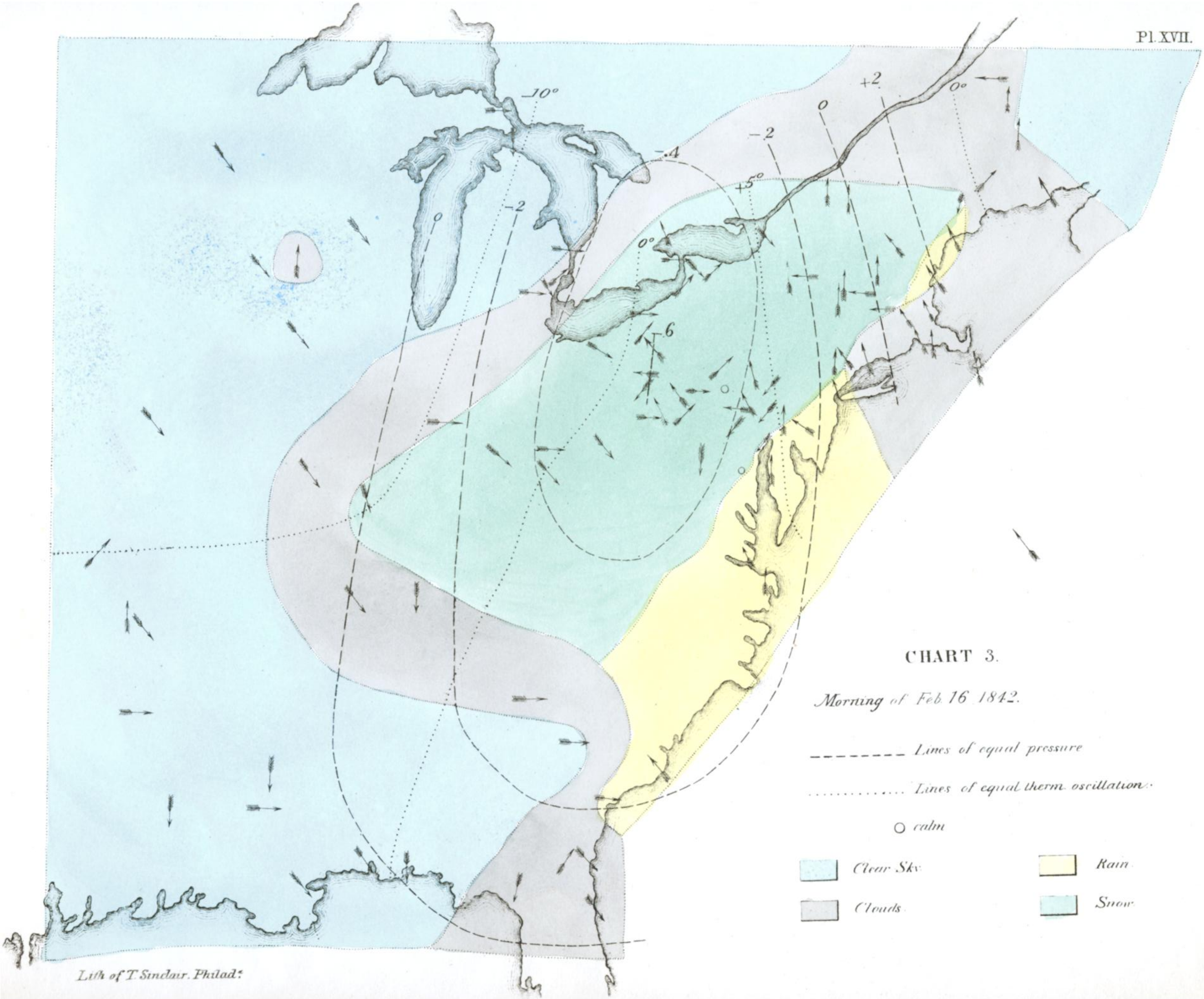

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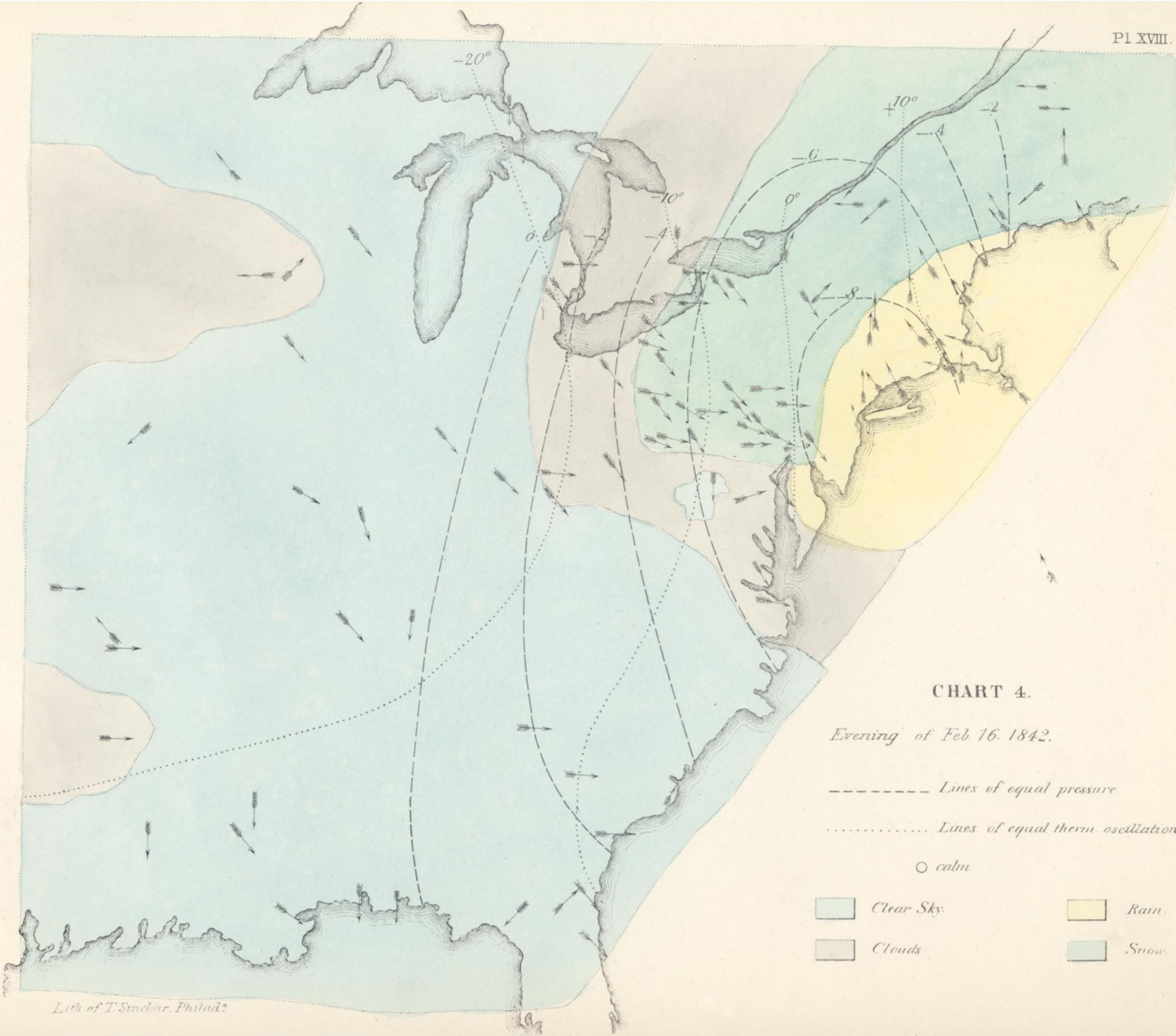

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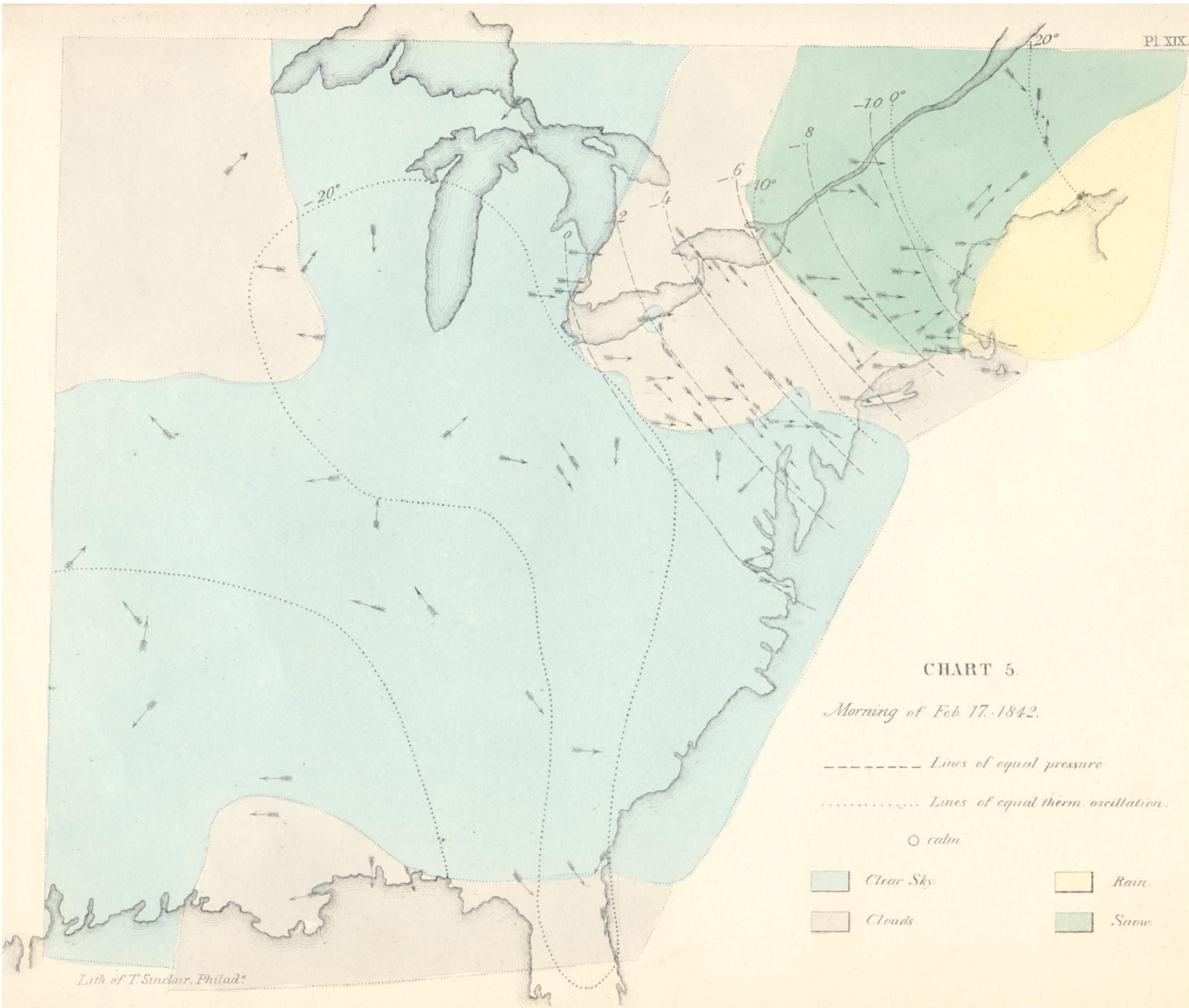

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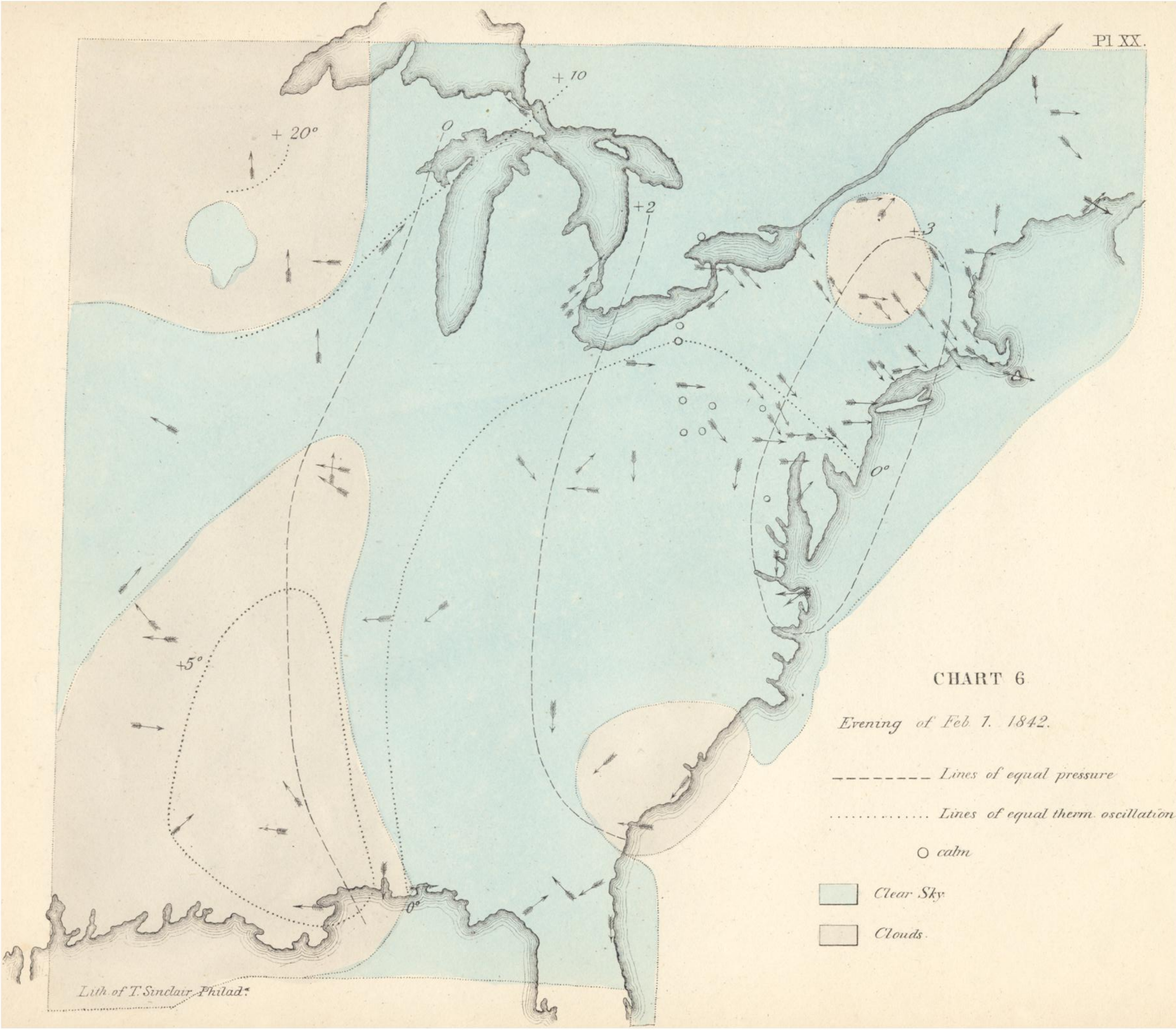


CHART 6
Evening of Feb. 7. 1842.
Lines of equal pressure
Lines of equal therm. oscillation.
calm
Clear Sky
Clouds.
+ 10
0
+ 20°
+2
+3
0°
+5°
0°
Lith. of T. Sinclair, Philad.a

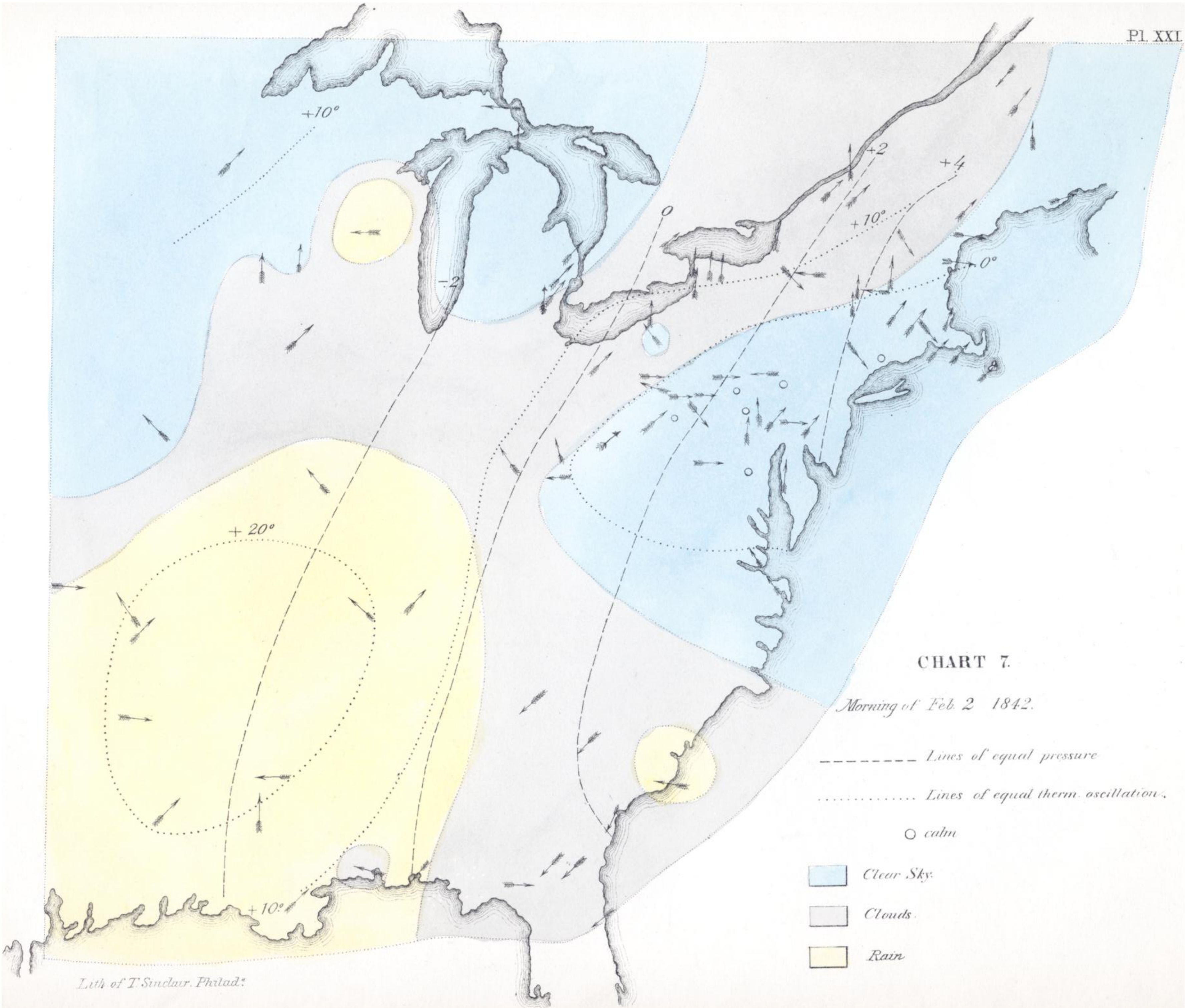


CHART 7.
Morning of Feb. 2 1842.
Lines of equal pressure
Lines of equal therm. oscillation.
calm
Clear Sky.
Clouds.
Rain
+10°
+20°
+10°
+10°
0°
-2
0
+2
+4
Lith of T. Sinclair. Philad.

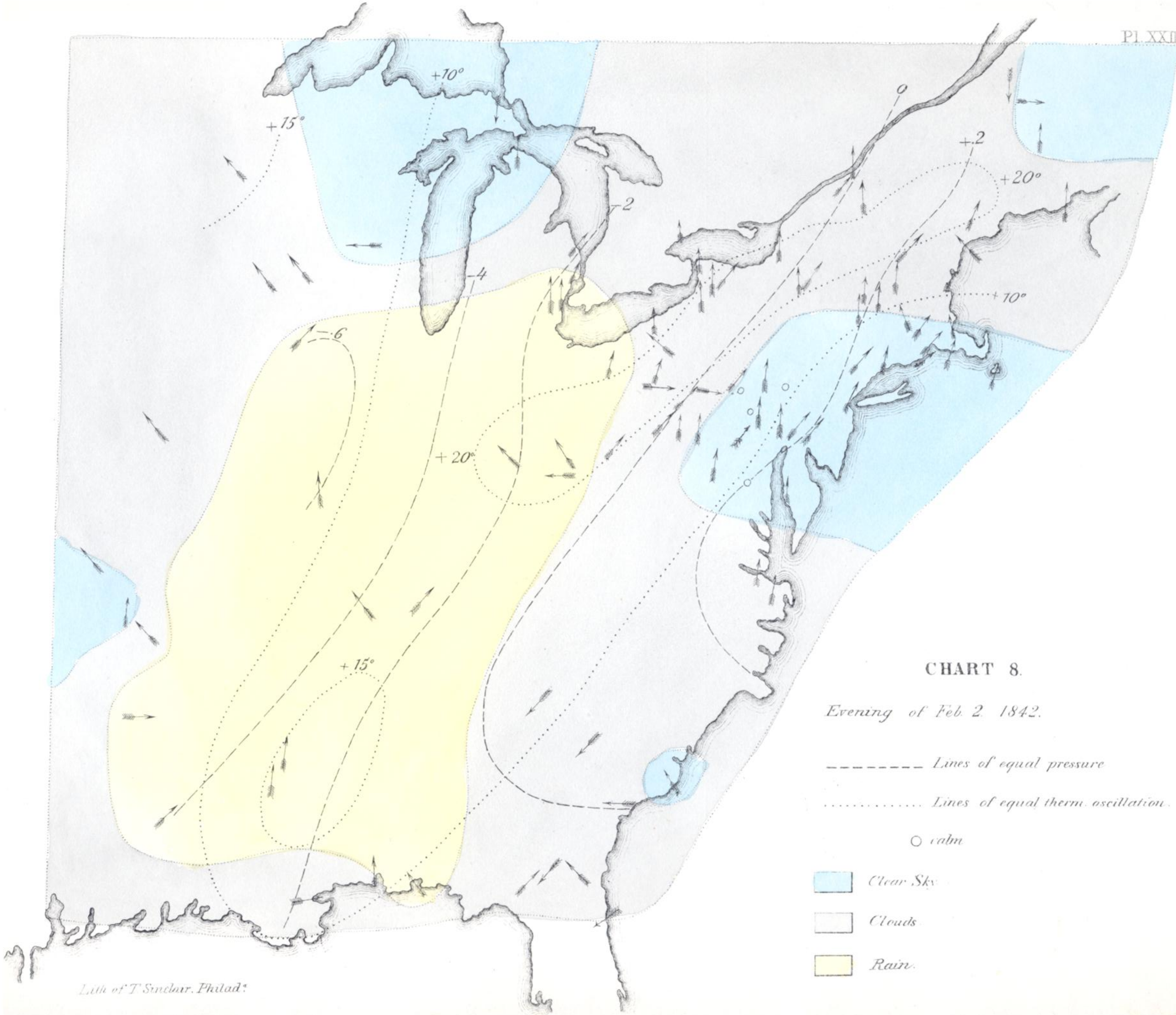
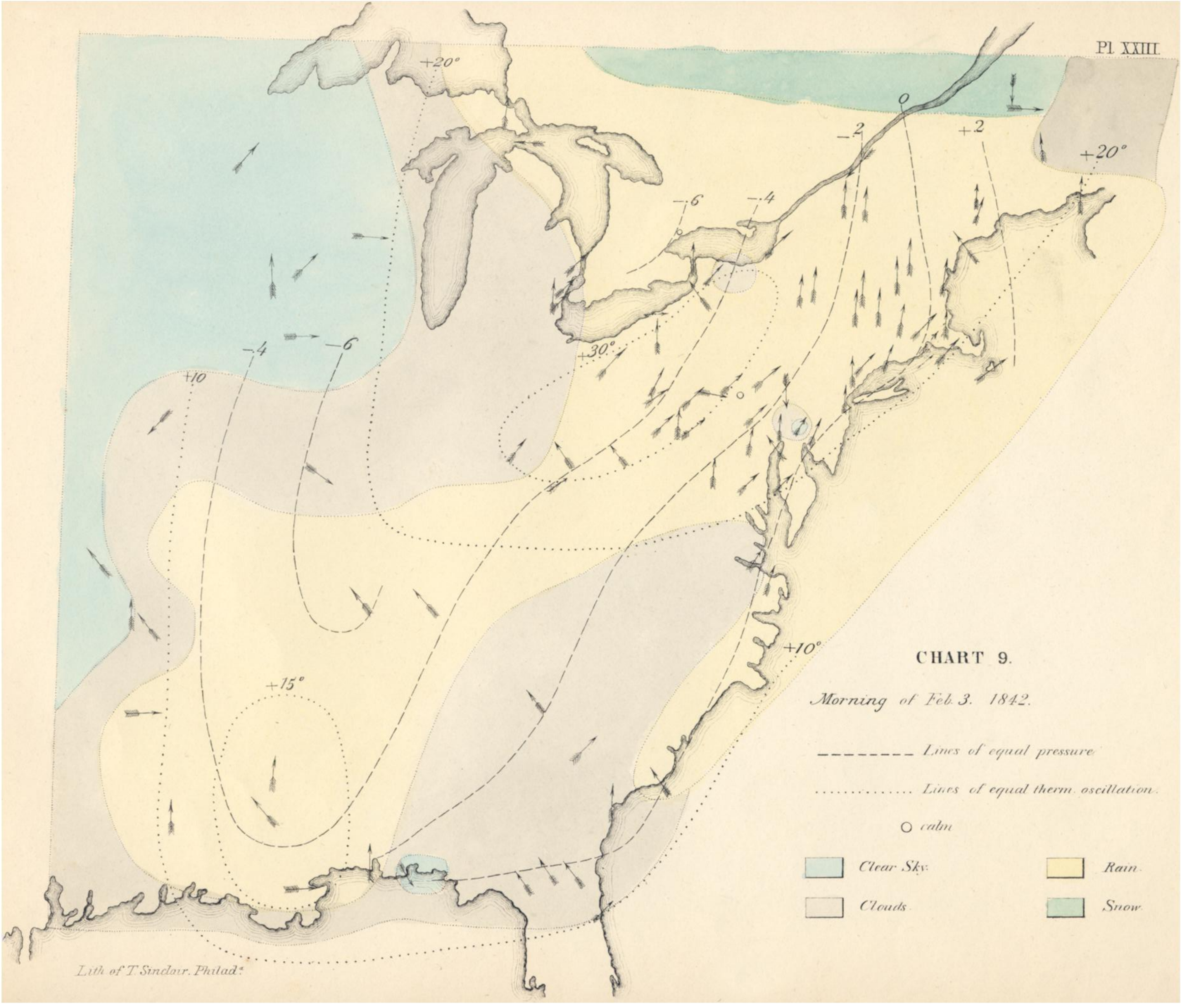
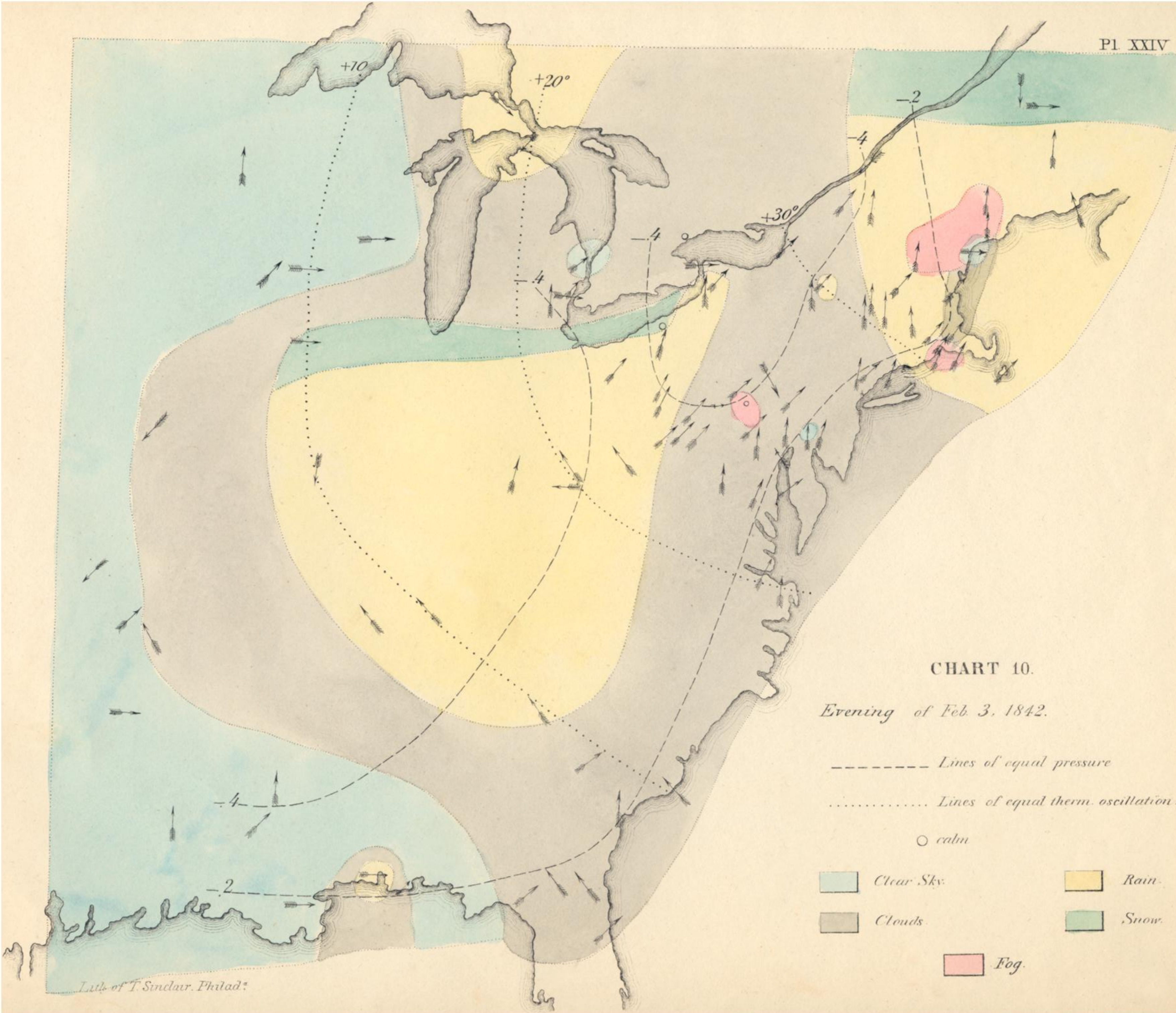


CHART 8.
Evening of Feb. 2. 1842.
Lines of equal pressure
Lines of equal therm. oscillation.
calm
Clear Sky
Clouds
Rain
+10°
+15°
+20°
+10°
+20°
+20°
+15°
0
+2
-2
-4
-6
Lith of T. Sinclair. Philad.


+20°
0
-2
+2
+20°
-6
-4
+30°
-4
-6
+10
+10°
+15°
CHART 9.
Morning of Feb. 3. 1842.
Lines of equal pressure
Lines of equal therm. oscillation.
calm
Clear Sky.
Clouds.
Rain.
Snow.
Lith of T. Sinclair, Philad.



+10
+20°
+30°
−2
−4
−4
−4
−4
−4
−2
CHART 10.
Evening of Feb. 3, 1842.
Lines of equal pressure
Lines of equal therm. oscillation.
calm
Clear Sky.
Clouds.
Rain.
Snow.
Fog.
Lith. of T. Sinclair. Philad.a

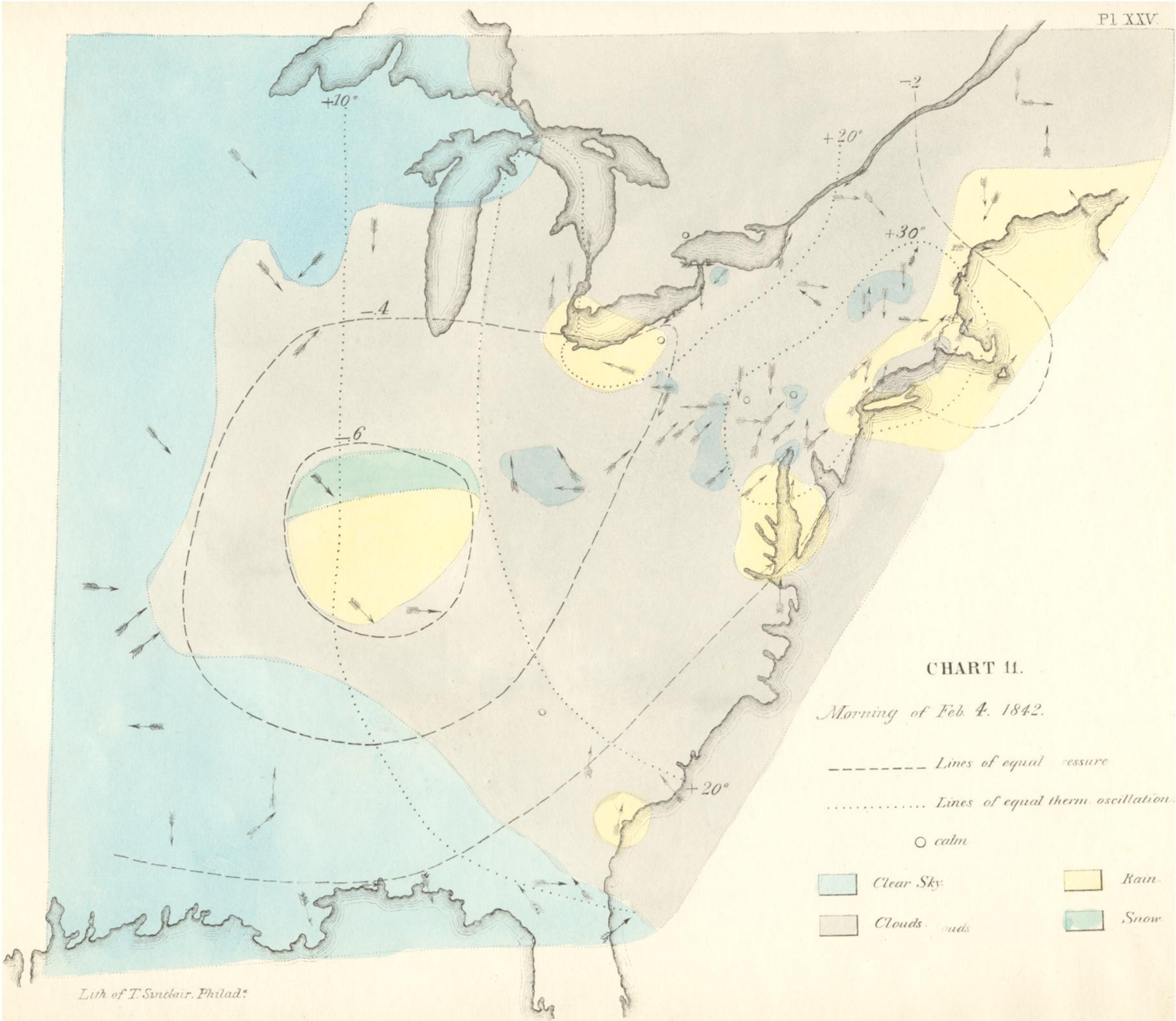
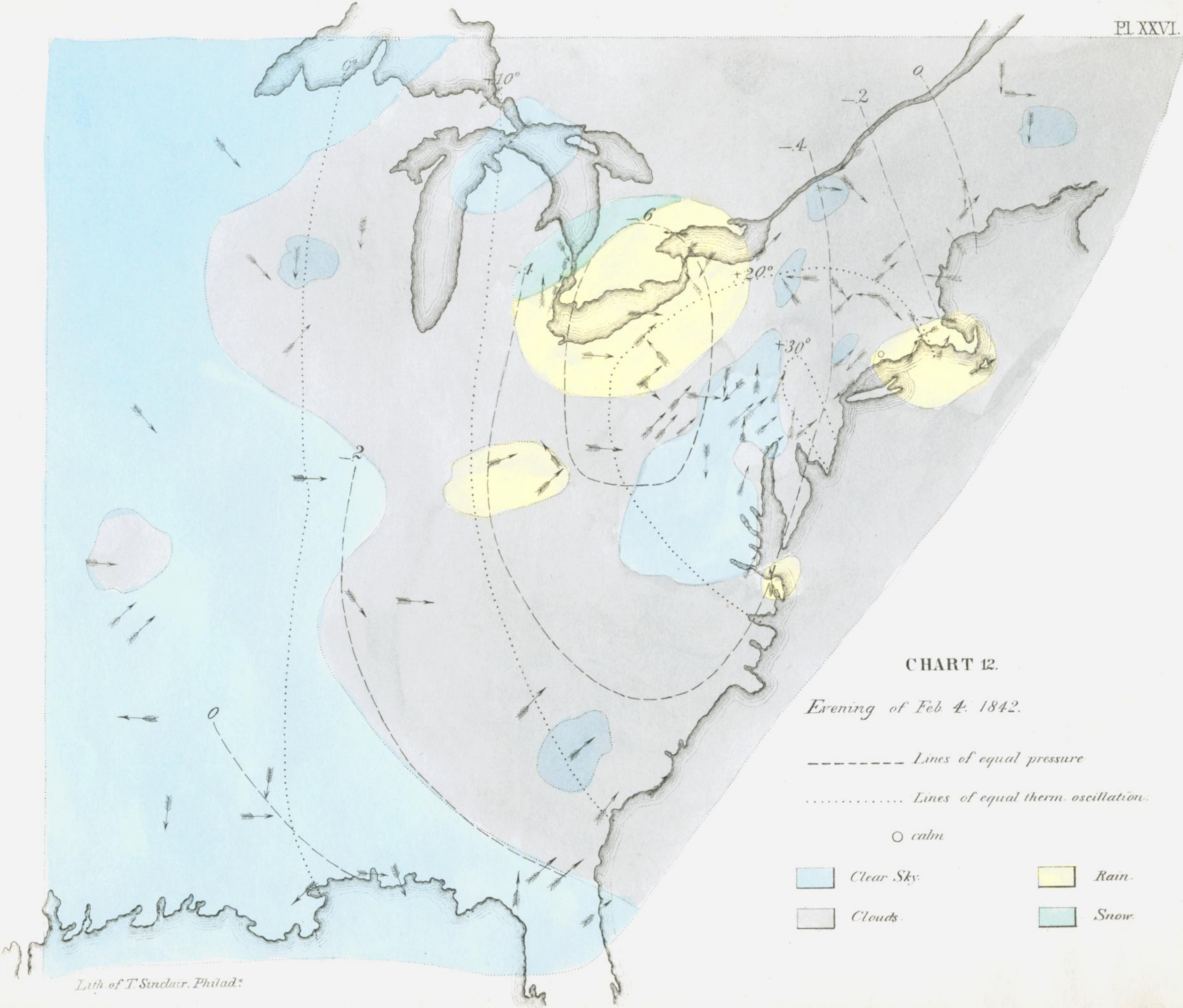


CHART 11.

Morning of Feb. 4. 1842.



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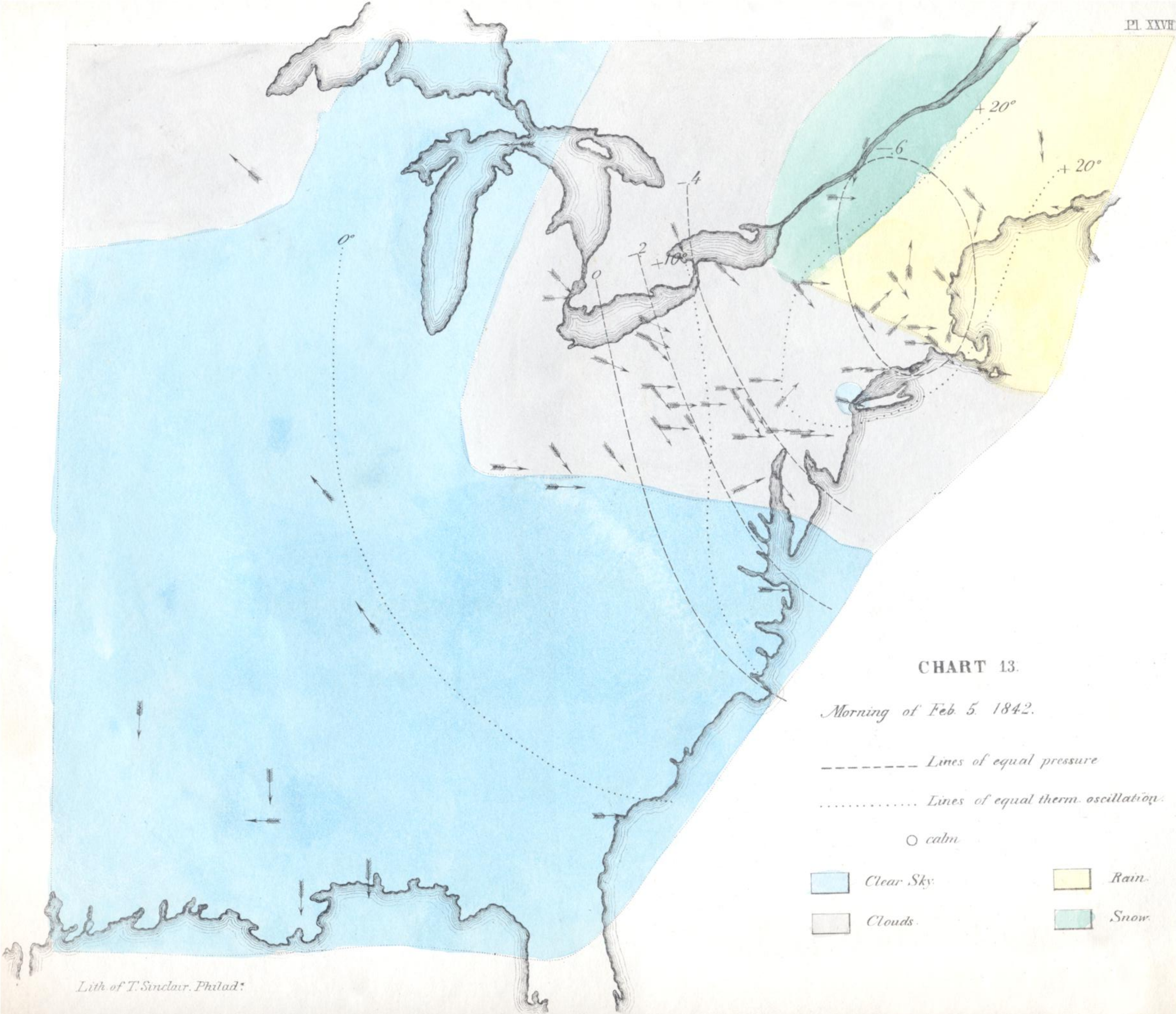
CHART 13.
Morning of Feb. 5. 1842.
Lines of equal pressure
Lines of equal therm. oscillation.
○ calm
Clear Sky.
Clouds.
Rain.
Snow.
0°
+20°
+20°
−6
−4
−2
+10°
0
Lith of T. Sinclair. Philad.ª